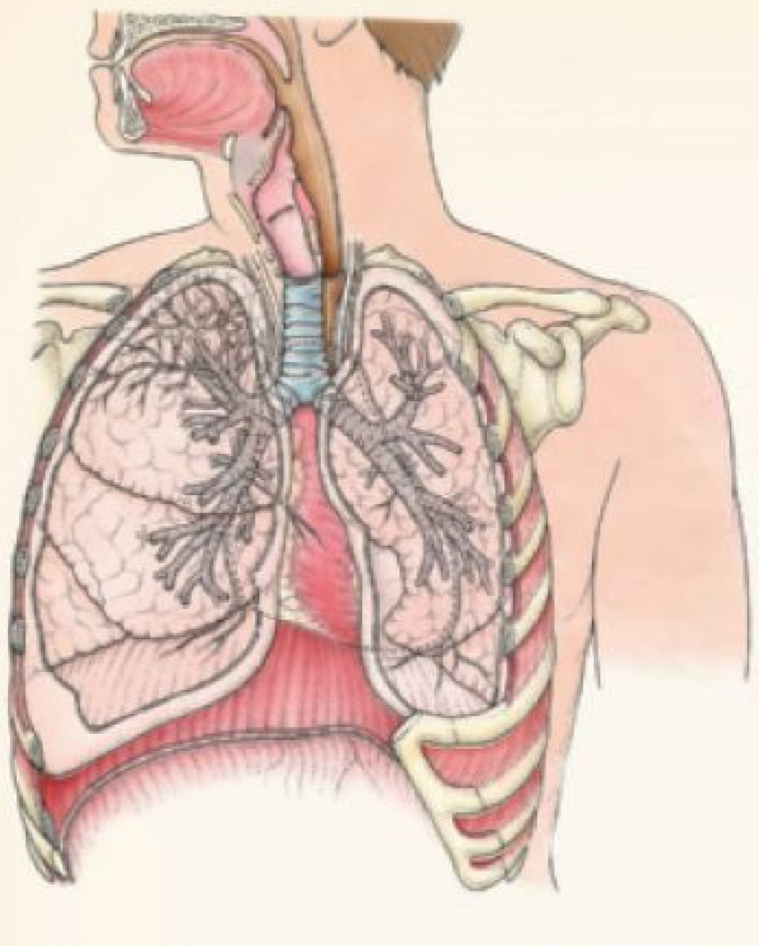
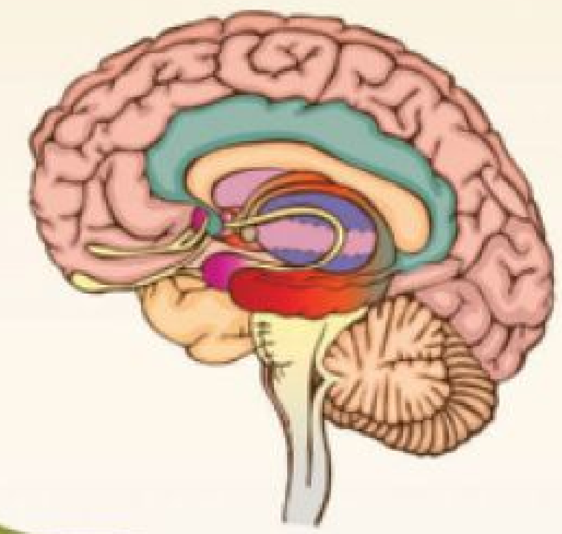
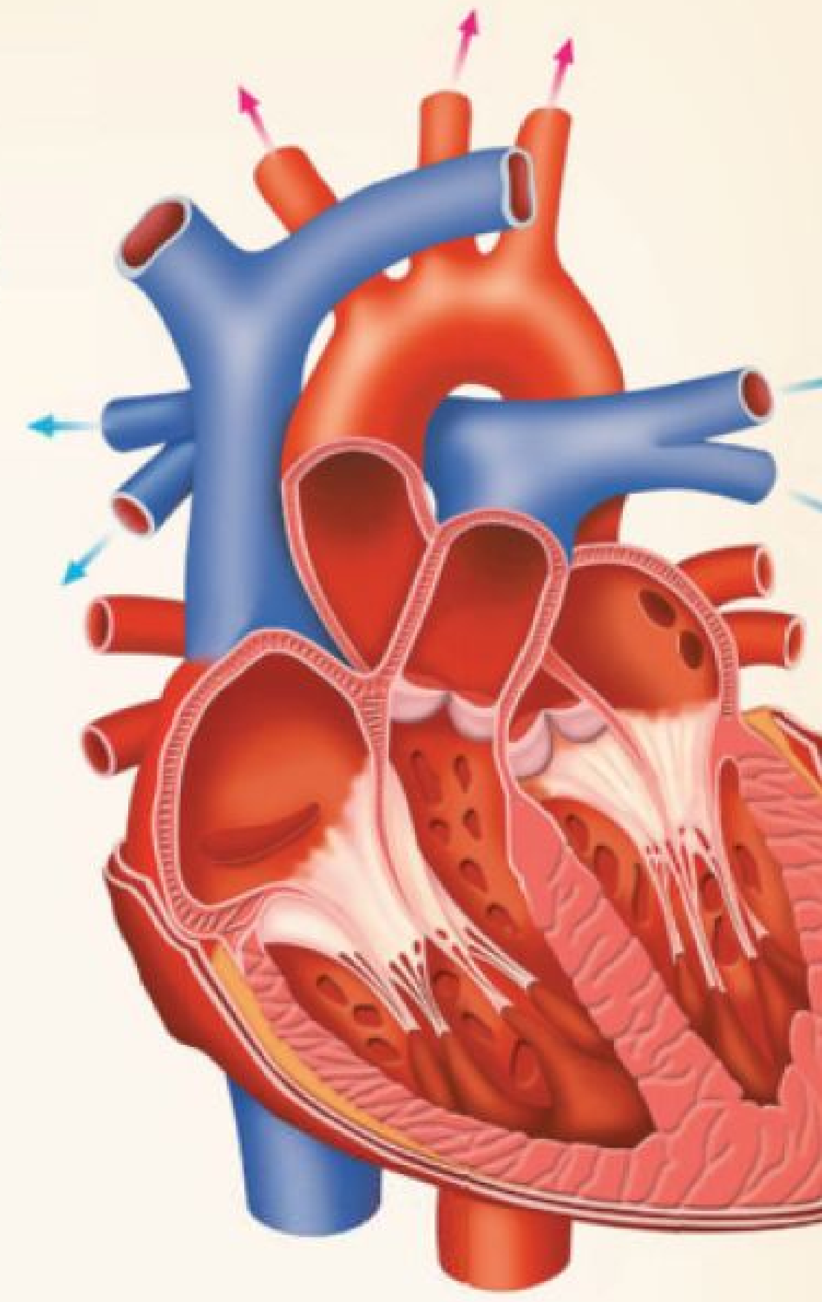
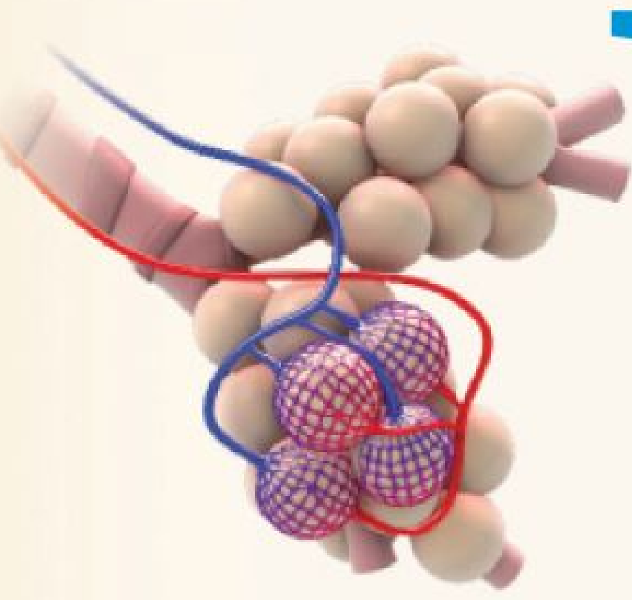
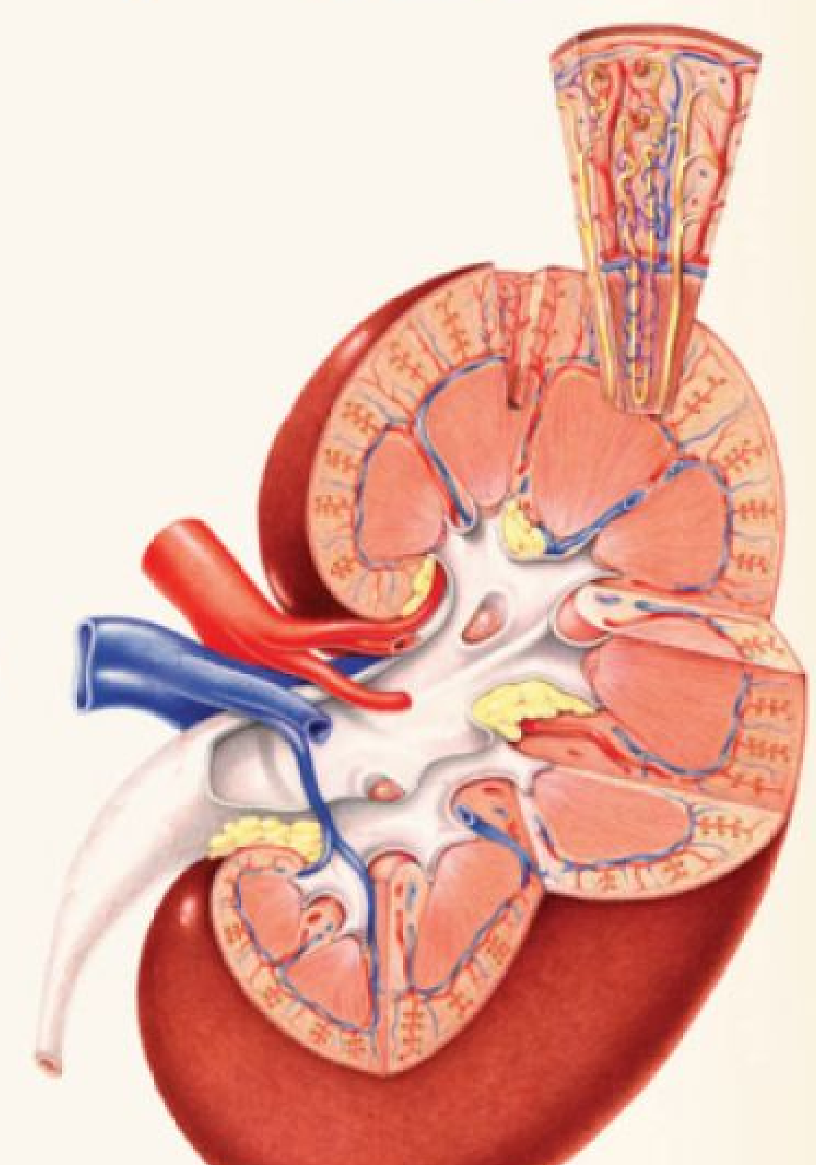
HOW IT WORKS
BOOK OF THE VITAL ORGANS

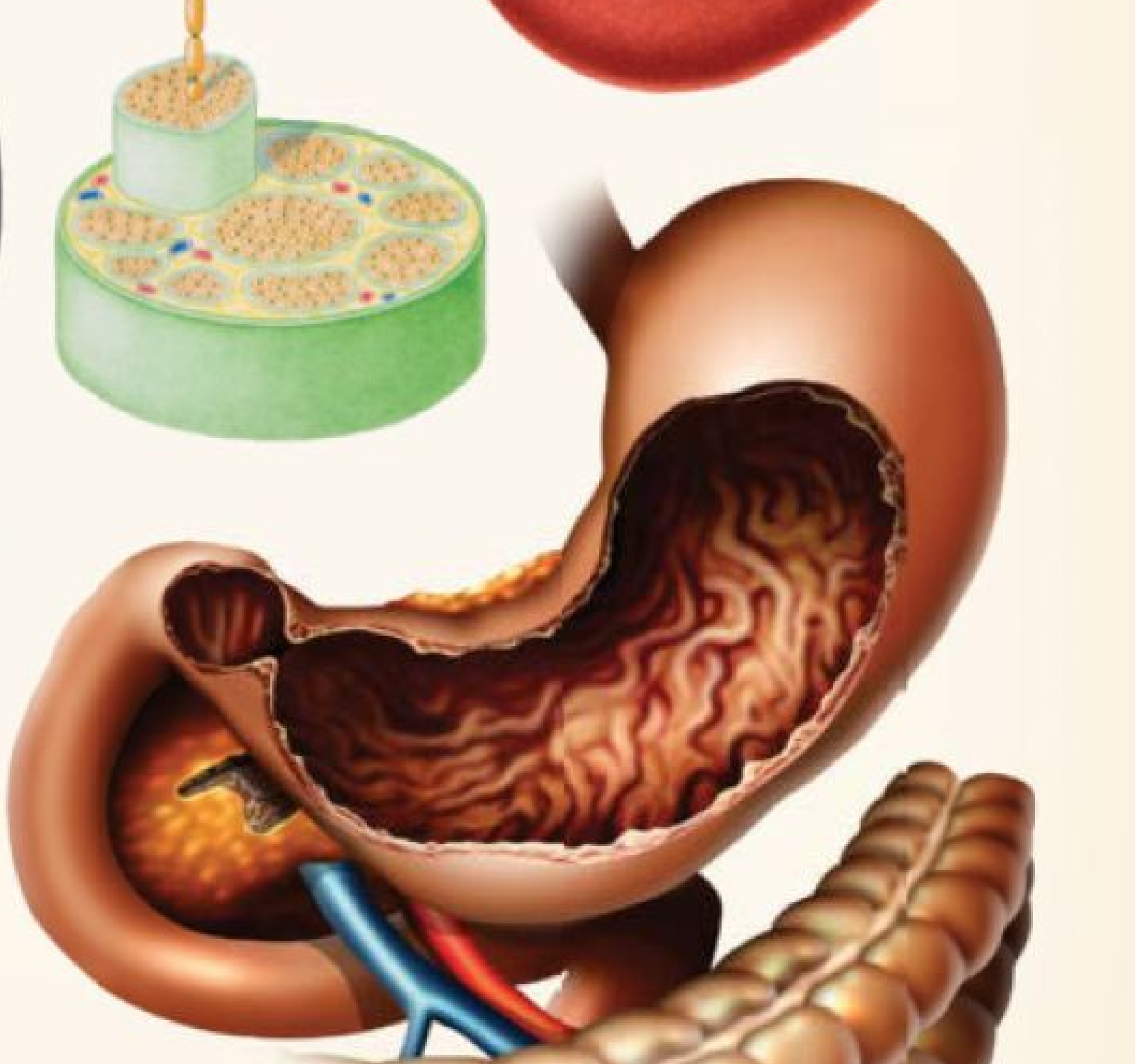
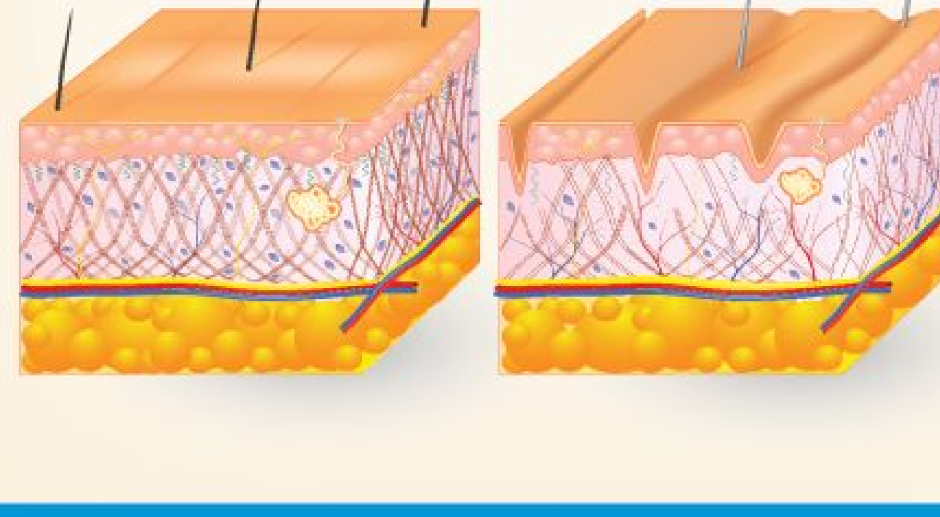
PART OF THE **HUMAN BODY** SERIES





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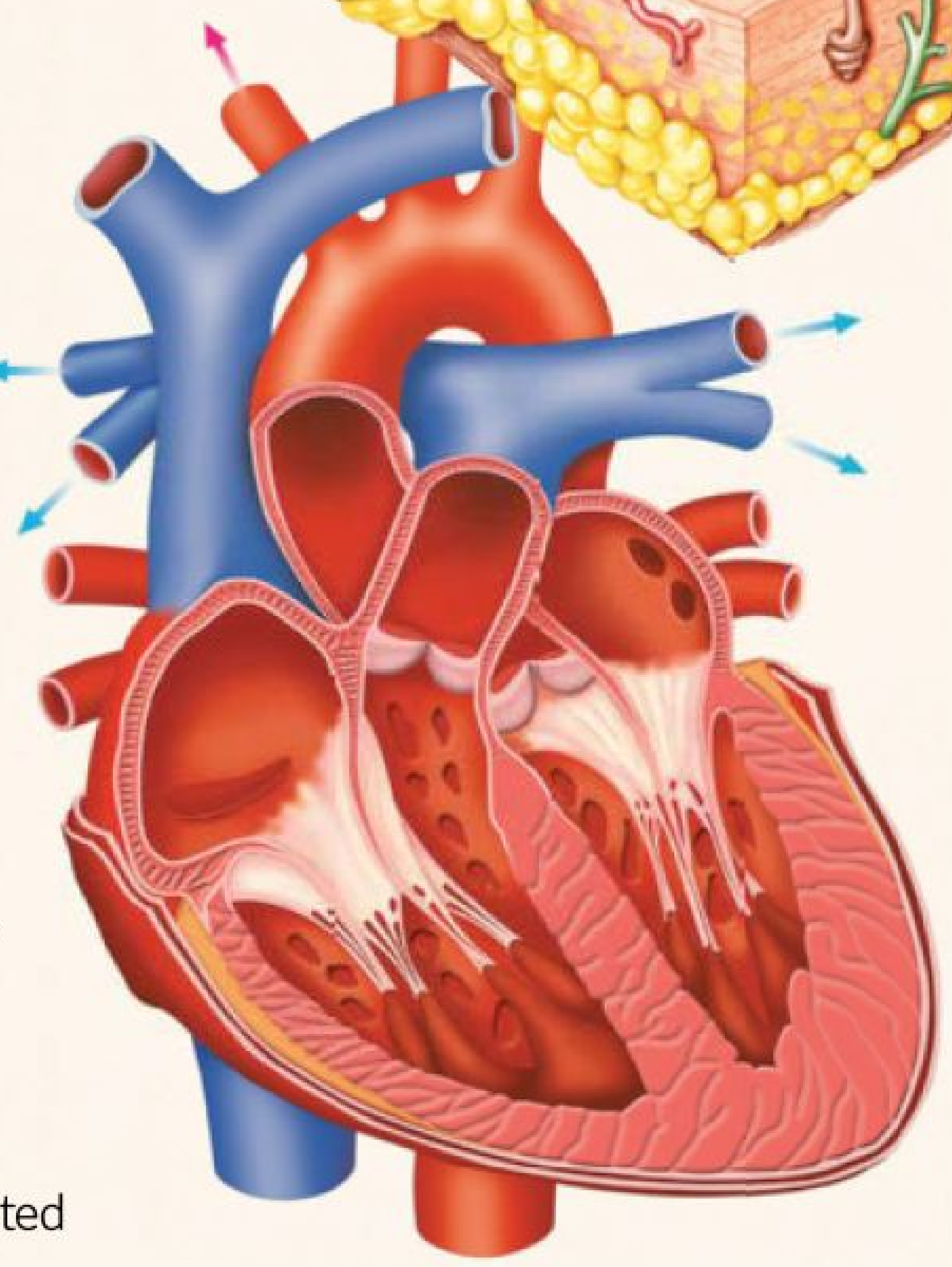

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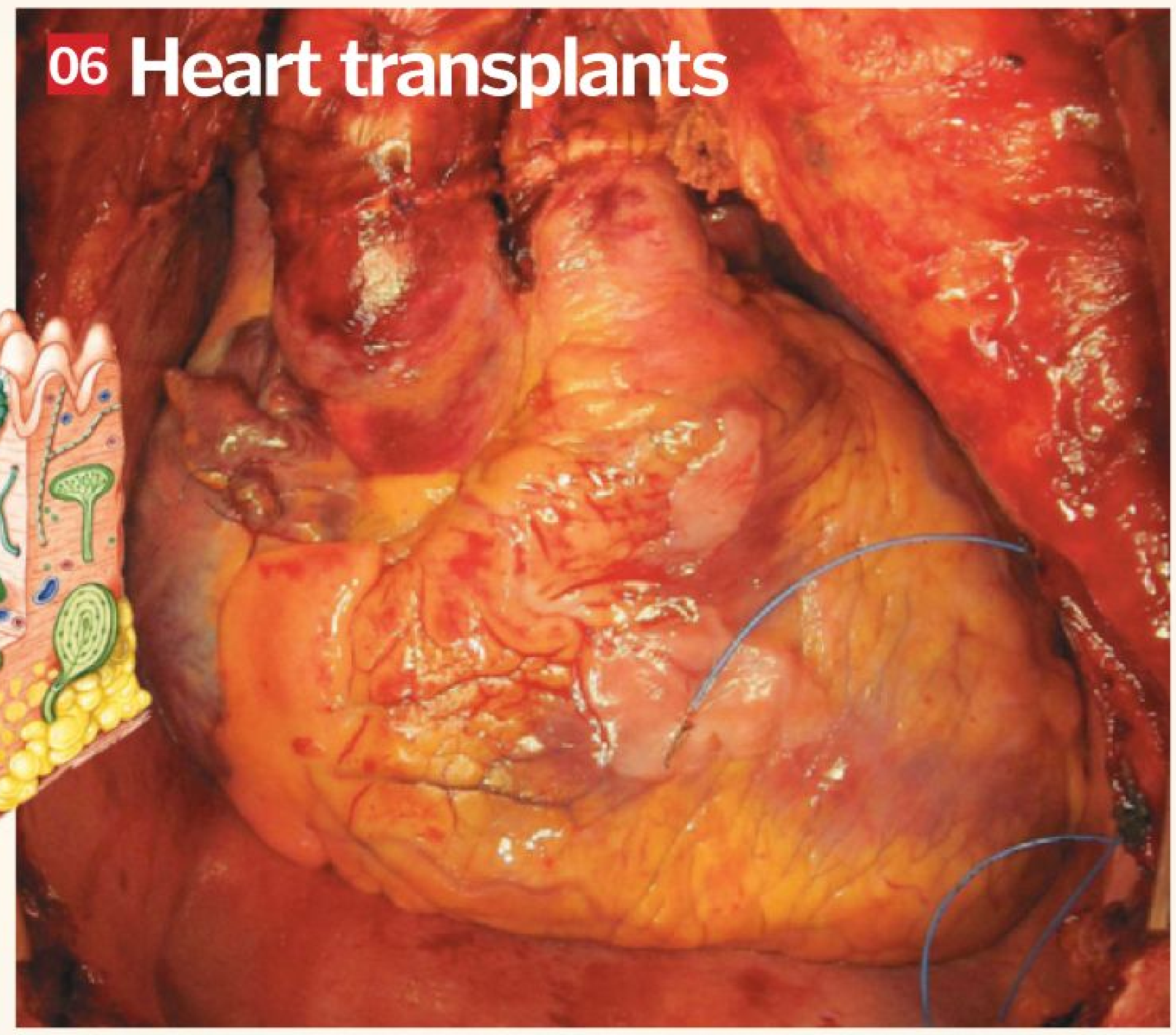

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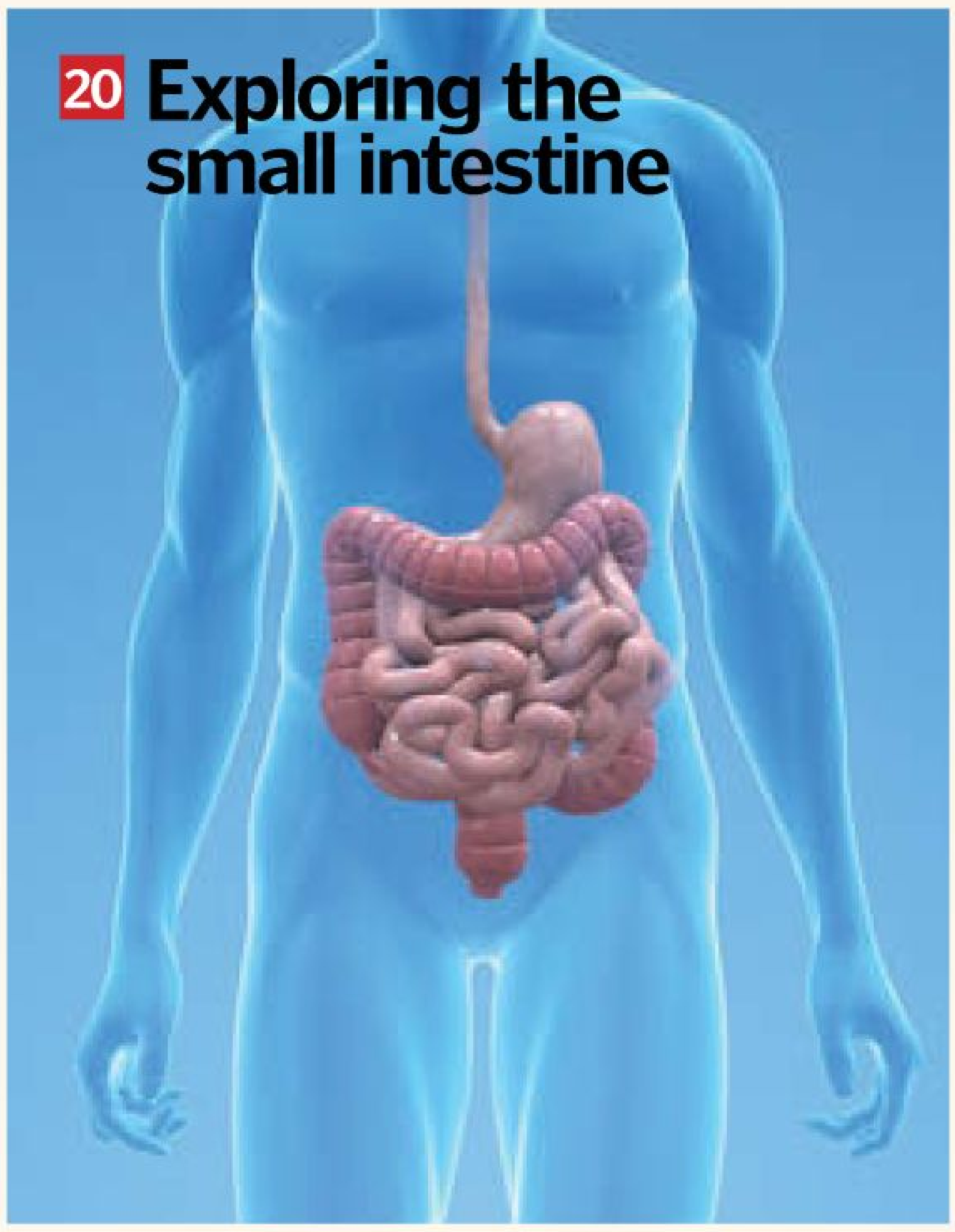
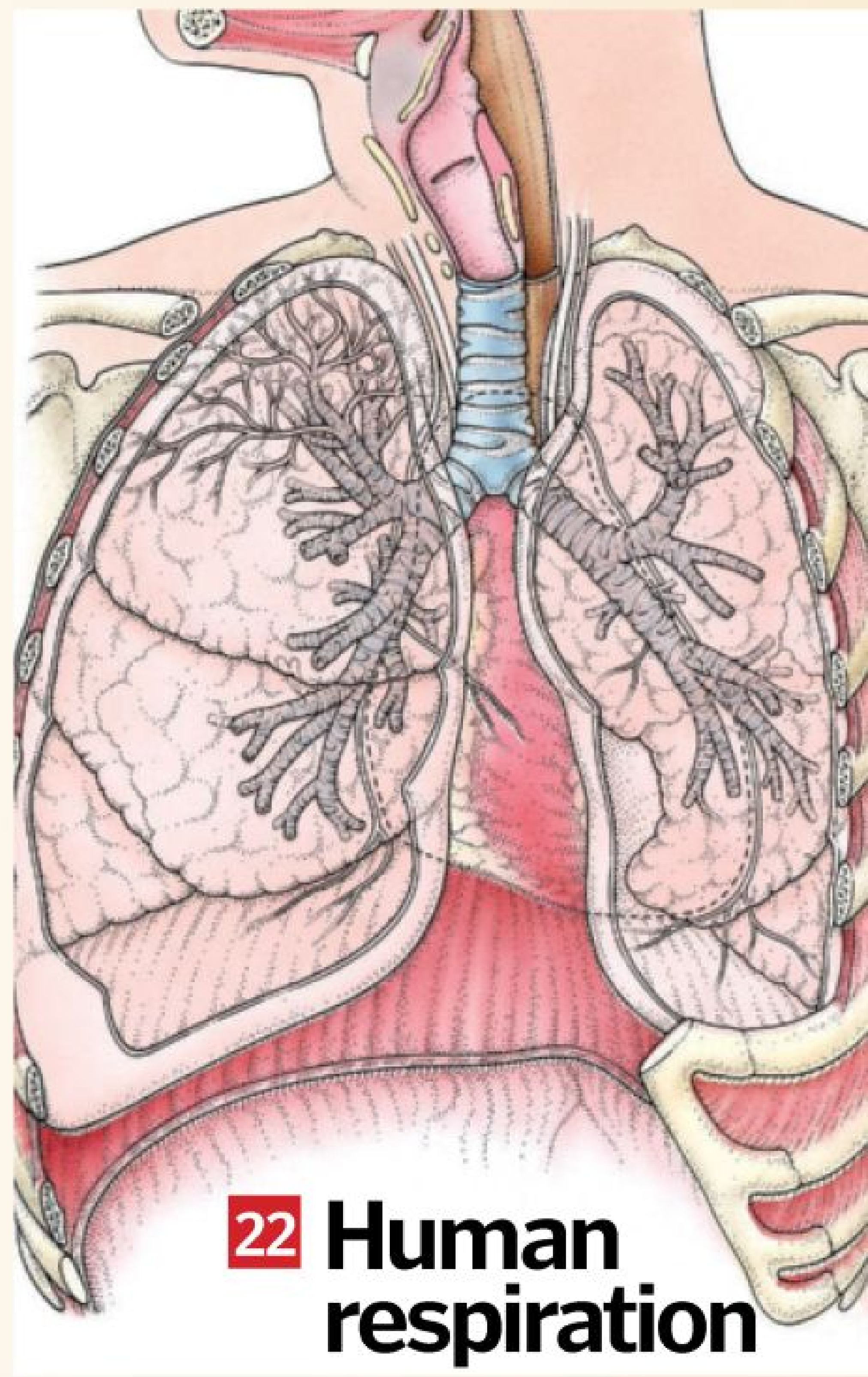
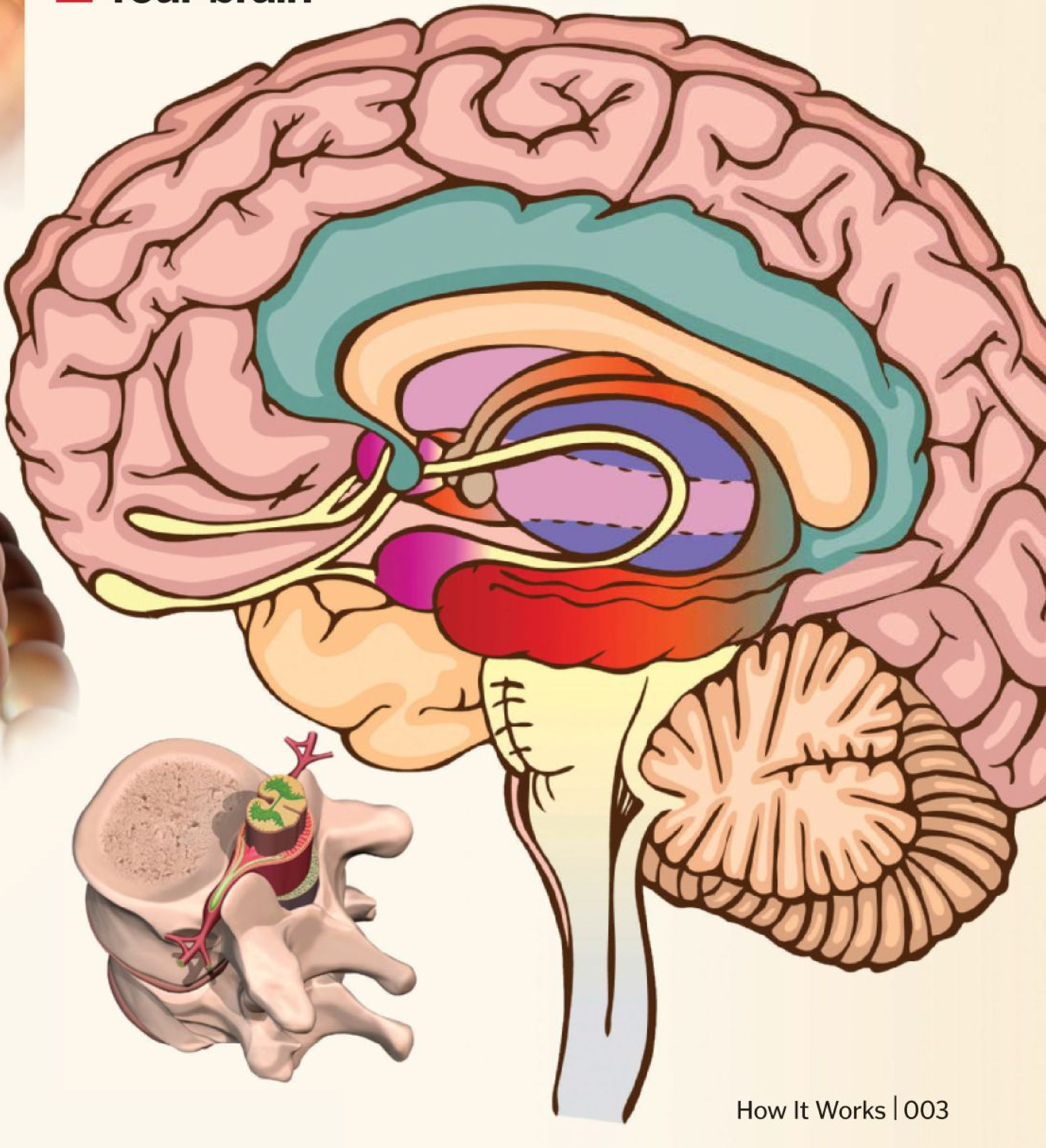
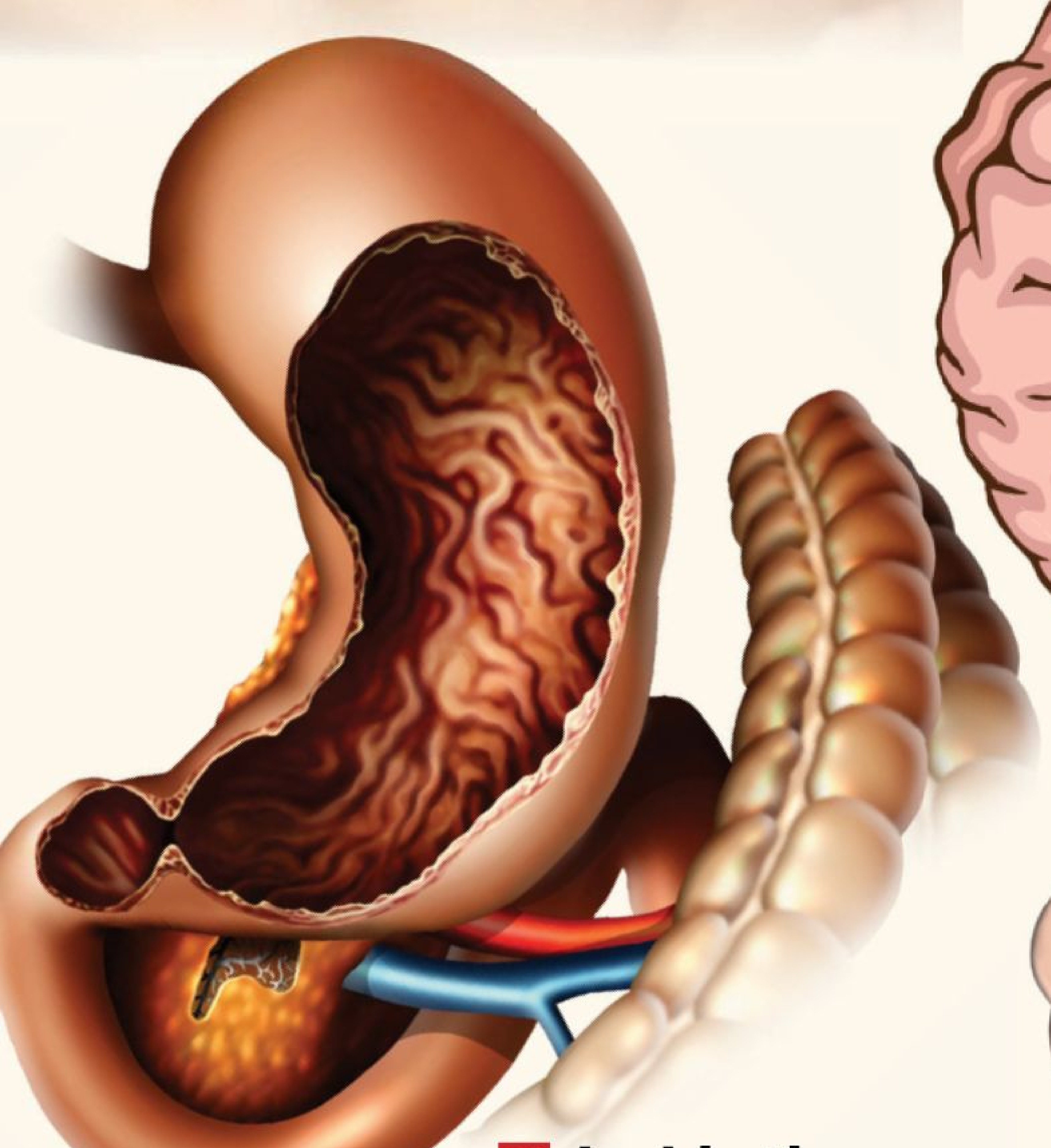








Under the skin

Find out more about the largest organ in your body…

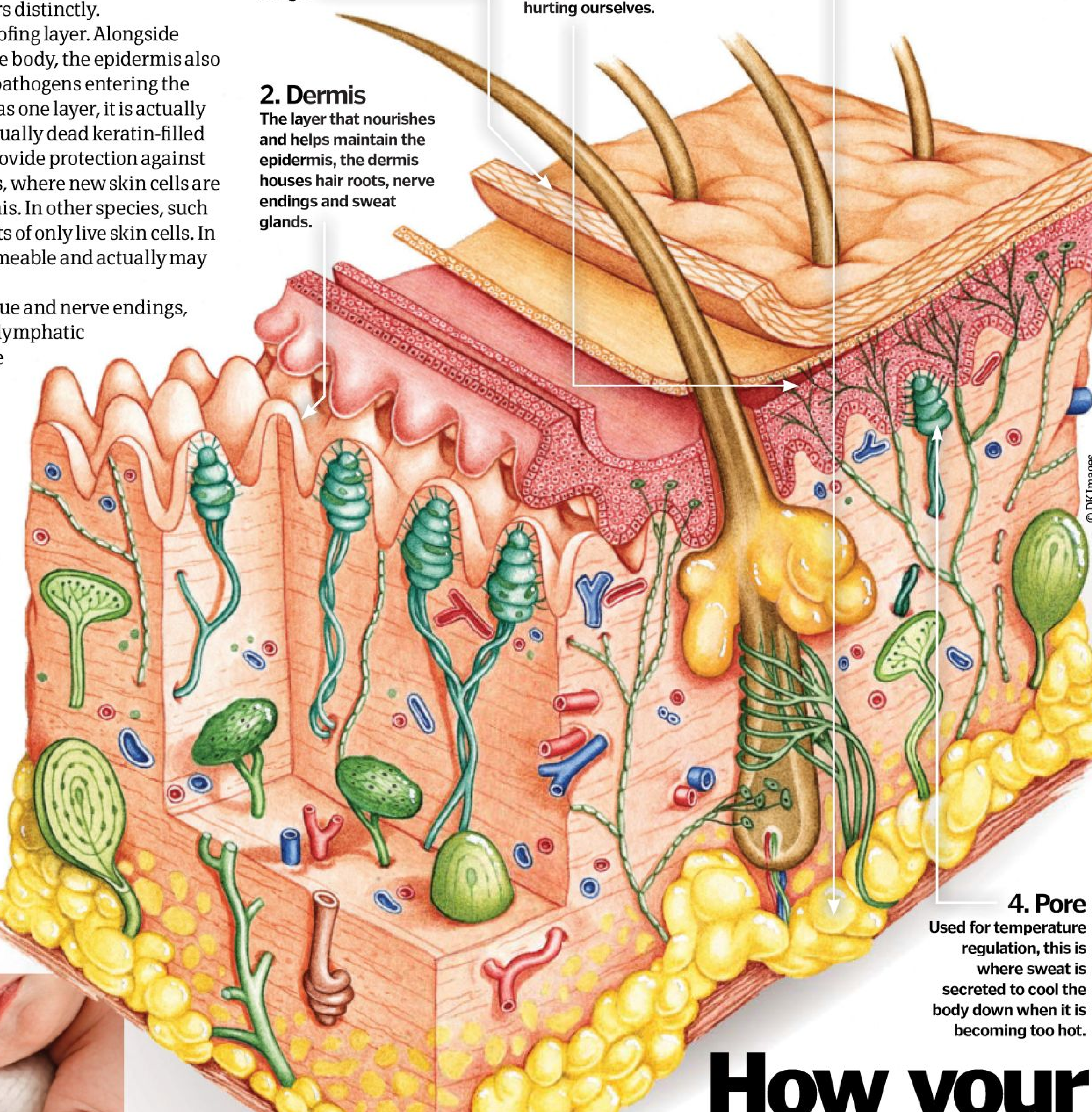
Our skin is the largest organ in our bodies with an average individual skin's surface area measuring around two square metres and accounting for up to 16 per cent of total body weight. It is made up of three distinct layers. These are the epidermis, the dermis and the hypodermis and they all have differing functions. Humans are rare in that we can see these layers distinctly.

The epidermis is the top, waterproofing layer. Alongside helping to regulate temperature of the body, the epidermis also protects against infection as it stops pathogens entering the body. Although generally referred to as one layer, it is actually made up of five. The top layers are actually dead keratin-filled cells which prevent water loss and provide protection against the environment, but the lower levels, where new skin cells are produced, are nourished by the dermis. In other species, such as amphibians, the epidermis consists of only live skin cells. In these cases, the skin is generally permeable and actually may be a major respiratory organ.

The dermis has the connective tissue and nerve endings, contains hair follicles, sweat glands, lymphatic and blood vessels. The top layer of the dermis is ridged and interconnects securely with the epidermis.

Although the hypodermis is not actually considered part of the skin, its purpose is to connect the upper layers of skin to the body's underlying bone and muscle. Blood vessels and nerves pass through this layer to the dermis. This layer is also crucial for temperature regulation, as it contains 50 per cent of a healthy adult's body fat in subcutaneous tissue. These kinds of layers are not often seen in other species, humans being one of few that you can see the distinct layers within the skin. Not only does the skin offer protection for muscle, bone and internal organs, but it is our protective barrier against the environment. Temperature regulation, insulation, excretion of sweat and sensation are just a few more functions of skin.

Baby-soft or old and wrinkly, skin is the largest organ in the body



1. Epidermis
This is the top, protective layer. It is waterproof and protects the body against UV light, disease and dehydration among other things.

2. Dermis
The layer that nourishes and helps maintain the epidermis, the dermis houses hair roots, nerve endings and sweat glands.

3. Nerve ending
Situated within the dermis, nerve endings allow us to sense temperature, pain and pressure. This gives us information on our environment and stops us hurting ourselves.

4. Pore
Used for temperature regulation, this is where sweat is secreted to cool the body down when it is becoming too hot.

5. Subcutaneous tissue
The layer of fat found in the hypodermis that is present to prevent heat loss and protect bone and muscle from damage. It is also a reserve energy source.

How your skin works

The skin is made of many more elements than most people imagine

5 TOP FACTS THE HEART

Bacteria thrive on human skin
1 Every square inch of skin has an average of 32 million bacteria on it… no matter how many baths or showers you have a day!

You shed skin every day!
2 Every 24 hours, you will lose your uppermost layer of dead skin cells, helping to keep your skin fresh and clean and able to breath.

Skin varies drastically in thickness
3 Skin is around 1mm thick on your eyelids, but on your feet this thickness increases to 3mm, giving you much more protection where needed.

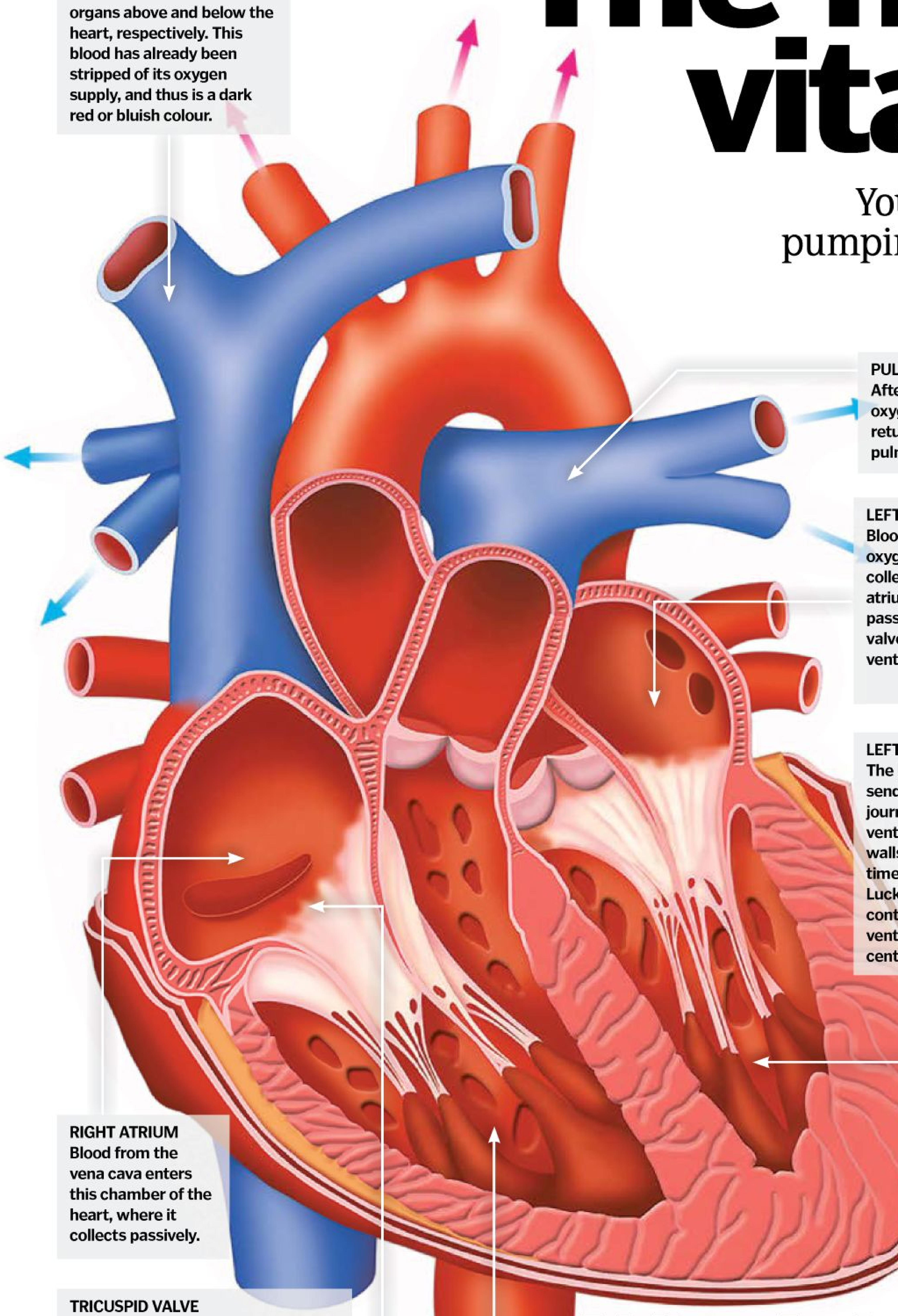
As we age, skin thins
4 Skin thins over time and begins to loosen, which is where wrinkles come from, and why people opt for plastic surgery in later life.

We have billions of sweat glands
5 Each square inch of healthy skin contains close to 650 sweat glands, which are essential for keeping you cool.

DID YOU KNOW? *The heart pumps about 1 million barrels of blood during the average lifetime*

The heart – a vital organ

Your heart is a turbocharged double-pumping muscle that beats more than 40 million times every year



What's inside your heart

Find out how your heart pumps blood around your body

Not only does your heart do amazing things, it does so tirelessly, every minute of every day from the moment you're born (actually, even a bit before then) to the instant that you die. It weighs somewhere between eight and 12 ounces – slightly more if you're male, less if you're female. Its sole purpose is to push blood through your circulatory system, providing crucial oxygen and other nutrients to all your organs.

The heart is considered a double pump because the right half sends 'used' blood to your lungs. There, the blood drops off a load of carbon dioxide and picks up some fresh oxygen, which you have helpfully provided by breathing. Then the oxygenated blood returns to the left half of the heart. This 'heart-to-lungs-to-heart-again' trip is known as pulmonary circulation. The left side of the heart then pumps this oxygenated blood to every organ in your body other than your lungs. Your brain, your skin, the muscles in your thigh, your spleen – they all get blood (and therefore oxygen) by virtue of your beating heart.

Even the heart itself gets blood, via a special set of veins and arteries known as the coronary system. The myocardial muscle within the wall of the heart needs oxygen and other nutrients to keep beating. Unfortunately, the coronary arteries that do this job are very narrow, between 1.7 and 2.2 millimetres in diameter. If they become clogged with cholesterol or other fatty deposits, the heart stops working. This is bad for you.

Of course, the relatively simple concept of the double pump is fairly complex in practice. A series of valves control blood flow to the heart's four chambers, allow for the build-up of enough blood pressure to get the job done, and direct the blood to the correct veins and arteries.

"After the operation, lifelong medications are taken to prevent the body rejecting the new heart"

Heart transplants

Discover what happens in one of the most complex surgeries

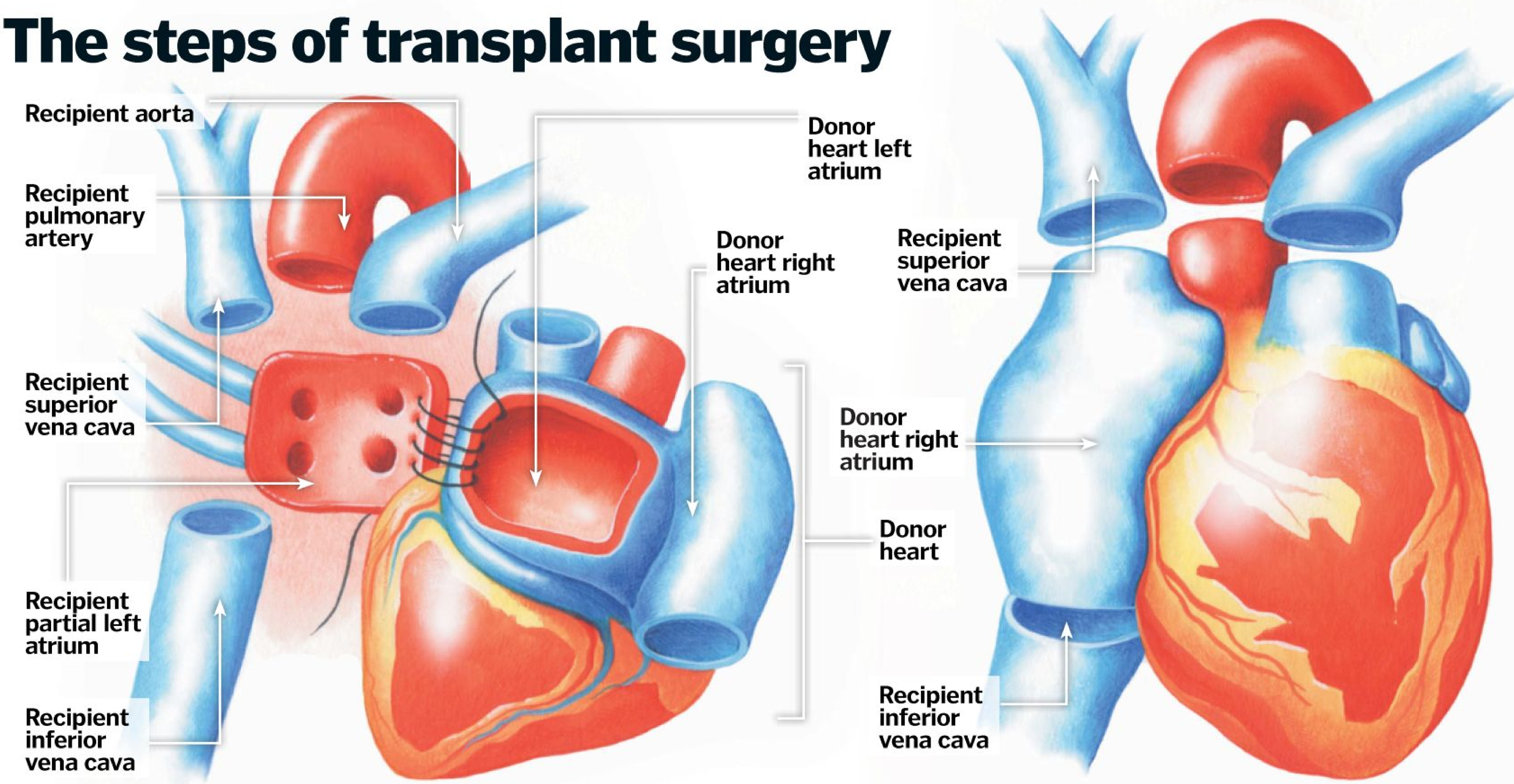
Heart transplants are a life-saving treatment that can restore a patient's quality of life.

Selecting suitable people for a heart transplant is a carefully controlled process. There are strict criteria to ensure maximum possibility of success, preventing wastage of any precious donor hearts. A heart transplant is recommended if a patient has severe heart failure, where not enough blood is being pumped around the body. Causes of this include diseases of heart muscles (cardiomyopathy) and a variety of genetic cardiac diseases. Patients typically have to pass psychological and emotional testing, be willing to take lifelong medications and have a current expected survival time of less than one year without transplant. Sometimes, newborn babies are affected, with ultrasound tests revealing structural problems meaning that the heart cannot pump enough blood. Further blood tests to rule out current infections and confirm tissue compatibility are performed.

The technical process of transplantation is complex and demanding for both patients and cardiac surgeons. The first step involves retrieval of the heart from the donor, at which time other organs might be harvested so that more patients can benefit. The receiving patient is given a general anaesthetic and a cut made through the breastbone (sternum) to access the heart. A heart-lung bypass machine is then started, and the heart transplant takes place. At the end of the operation, the new heart is tested, and if it's pumping blood successfully, the bypass machine is removed, the breastbone closed and the patient is moved to an intensive care unit.

After the operation, lifelong medications are taken to prevent the body rejecting the new heart. These include immunosuppressants, which reduce the patient's natural immunity, so their body does not reject their new heart.

The steps of transplant surgery



First incision

The sternum is cut with a special saw that doesn't damage the softer tissues underneath. The sac containing the heart (pericardium) is cut open and the patient placed on a heart-lung bypass machine. The blood vessels and chambers of the old heart are disconnected, leaving the back wall of the left atrium in place, which acts as the starting point for attaching the new heart.

Attaching the heart

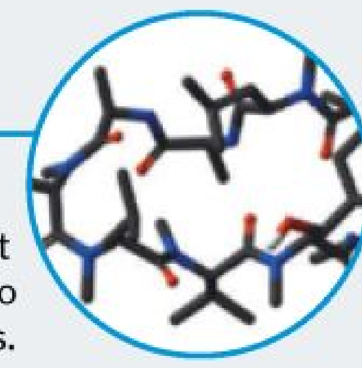
The veins carry blood back toward the heart. The biggest – the inferior and superior vena cava – drain into the right atrium. These are carefully attached to the new heart, which fixes the donor right atrium into place. Tiny stitches are sewn using very sharp needles, special needle holders and a steady hand!

KEY DATES
TRANSPLANT MILESTONES

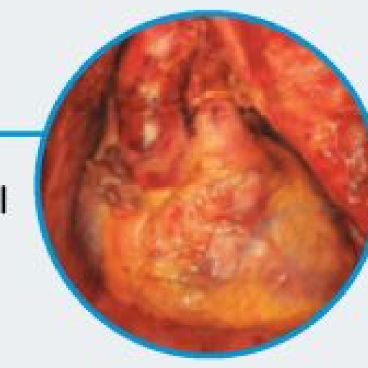
2000 BCE
Evidence of heart disease has been found in 4,000-year-old Egyptian mummies.

1967
The first human-to-human heart transplant takes place in South Africa, by Christiaan Barnard.

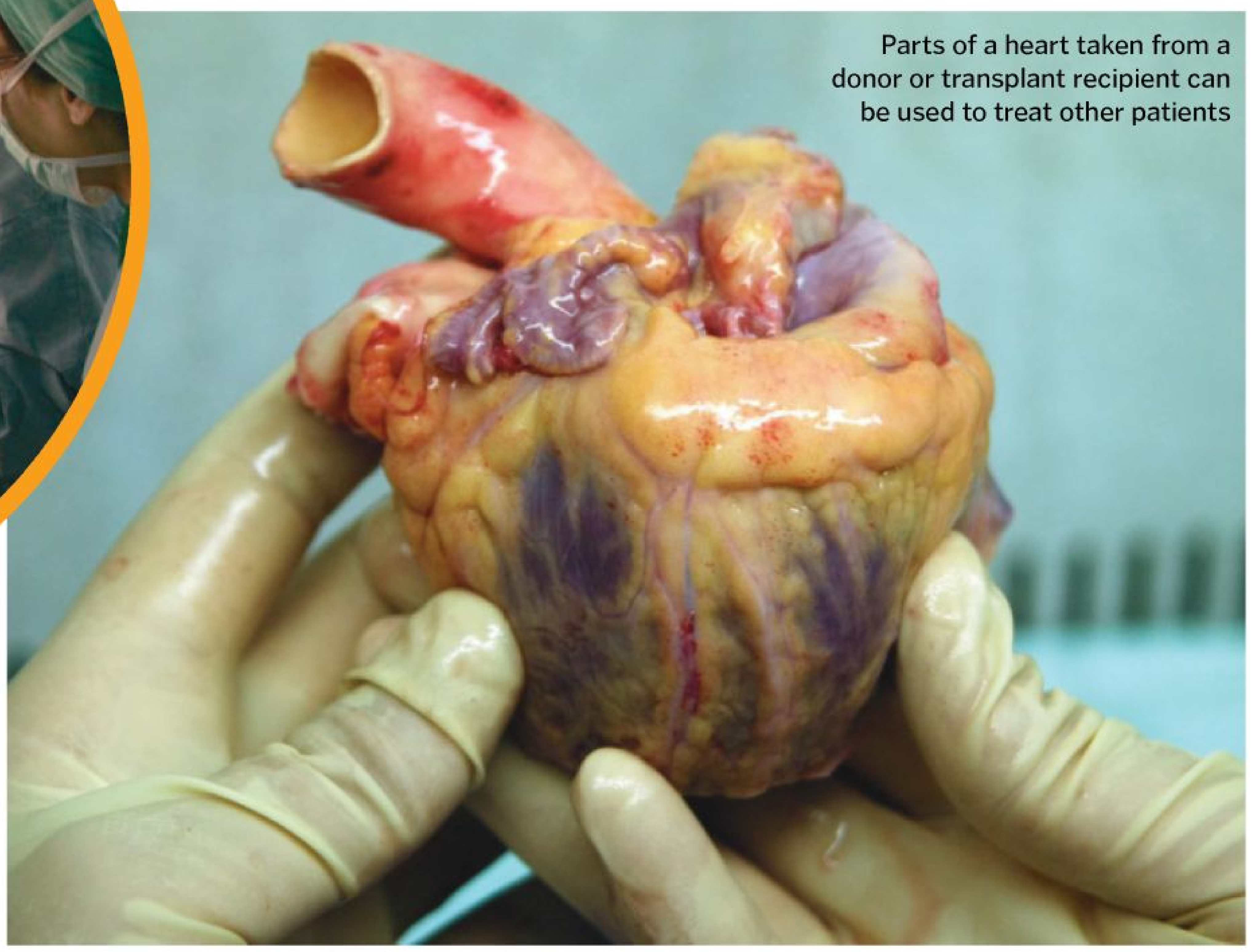
1971
Cyclosporine, an immuno-suppressant that prevents rejection, helps to advance heart transplants.



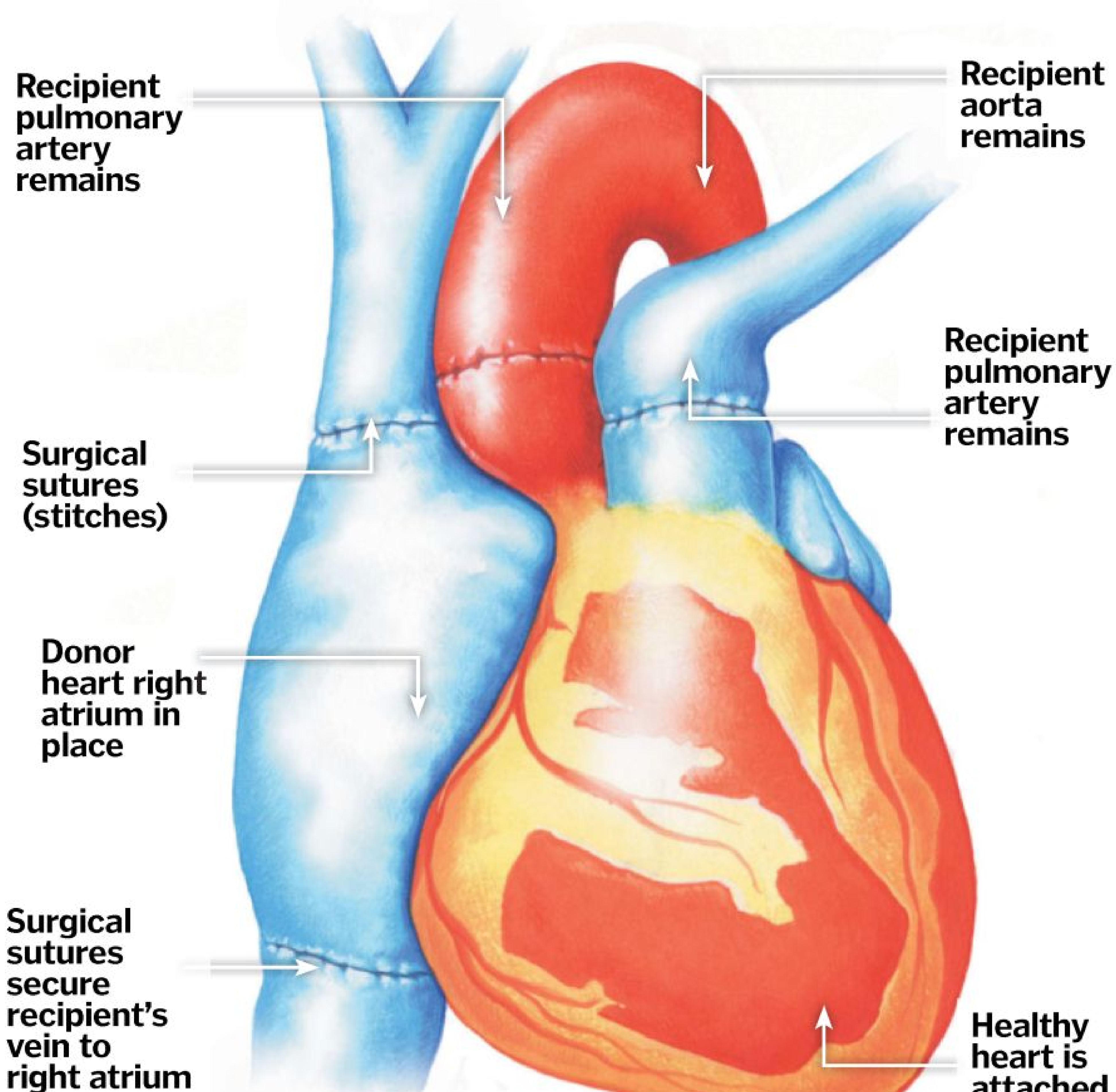
1982
The first successful artificial heart is transplanted into a human being. The patient survives fro 112 days.



DID YOU KNOW? *The human heart is not heart shaped – the popular heart shape was widely used on T-shirts in the 1970s*

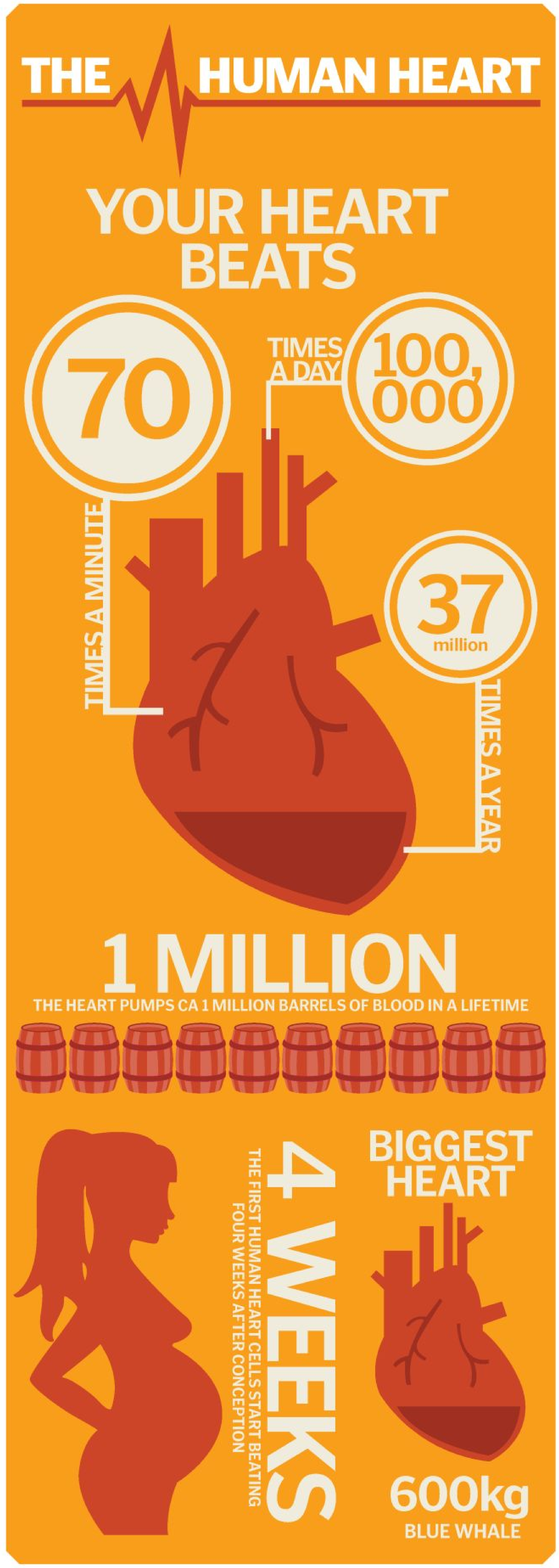


Parts of a heart taken from a donor or transplant recipient can be used to treat other patients



Completing the operation

The final steps include attaching the body's biggest and strongest artery – the aorta. This pumps oxygenated blood to the entire body and is under the highest pressure. The vessel bringing oxygenated blood back from the lungs (the pulmonary vein) is also attached. The clamps controlling the vessels are removed and the new heart started with a small burst of electricity.



> "A malignant melanoma is a rare kind of skin cancer that can occur in melanocytes"

How wrinkles form

Discover how the body's largest organ loses its elasticity over time

Wrinkles are an inevitable part of the natural ageing process. There are two different types of wrinkles; dynamic wrinkles, which develop due to repeated muscle movements, such as smile lines around the mouth, and static wrinkles caused by environmental factors, lifestyle habits and the ageing process. Static wrinkles are visible even when your face is at rest and often deepen over time. They are caused by a loss of skin elasticity, fat and collagen.

The skin itself is made up of three layers. The epidermis layer on the surface is made up of dead skin cells and protects the body from outside elements such as water and sunlight. Beneath this layer is the dermis, which is responsible for the skin's strength and elasticity, as it's rich in collagen and elastin fibres. The base layer, known as the hypodermis, is where fat cells that give the skin its plump youthful appearance reside.

Over time, wrinkles will start to form on both the epidermis and dermis layers. As we age, our skin cells take longer to divide, which means the skin repairs at a much slower rate than when it's young. As a result of this, the dermis layer will begin to thin out, and fine lines start to form on the epidermis due to a loss of moisture. Eventually, collagen and elastin will break down in the dermis layer, which reduces support so the skin is unable to ping back as quickly when stretched. Fat will also begin to deplete in the hypodermis layer, causing the skin to sag and appear much less plump.

Wrinkles are caused by a loss of collagen, fat and elasticity in the skin

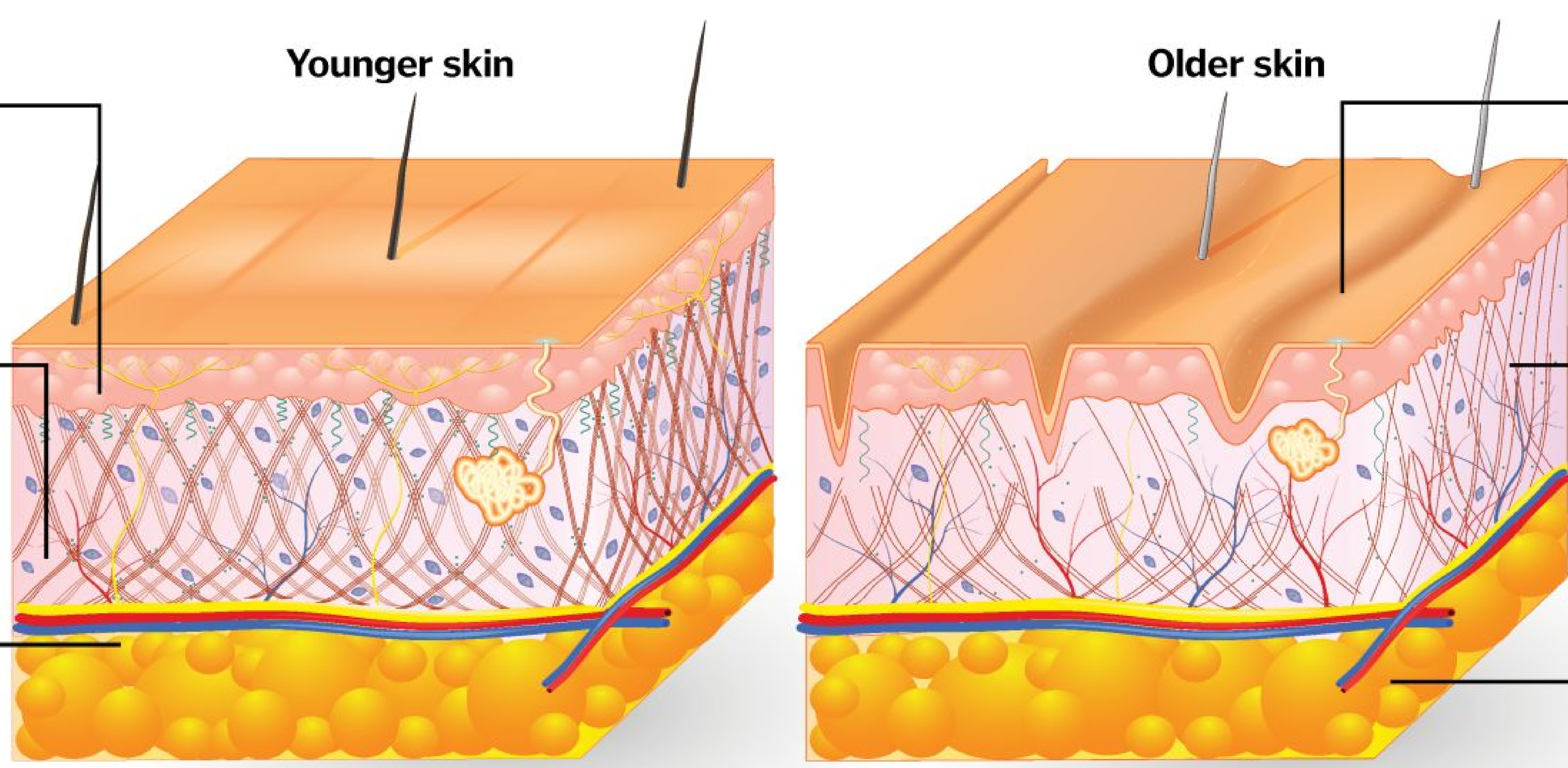
What causes wrinkles?

The beauty industry makes millions of pounds every year with products that promise to slow down the ageing process and vanquish already visible lines and wrinkles. Unfortunately, wrinkles are unavoidable as we age, but their development can be slowed to some extent with a few preventative measures. Exposure to sunlight is in fact most detrimental to your skin, as ultraviolet rays can break down collagen and elastin fibres in the dermis layer, which leads to the skin losing its strength and elasticity. So keeping your skin suitably covered and protected with a high-factor sun cream will help to protect it from harmful UV radiation.

Genetic factors, stress and repeated facial expressions can also play a part in how quickly wrinkles form, while ditching bad habits such as smoking, which reduces blood supply to the skin, will also help delay the onset of fine lines and wrinkles.

The ageing process

A closer look at how wrinkles form in the skin



Holding moisture
Youthful skin is softer and smoother as it holds much more moisture in the epidermis layer than older skin.

Dermis layer
The dermis layer provides support and gives skin its elasticity as it's packed full of elastin fibres and collagen.

Plump appearance
Fat cells are stored in the hypodermis layer and are responsible for plumping up younger skin.

Deep wrinkles
Fine lines start to develop due to a lack of moisture before eventually deepening as the dermis layer weakens.

Less collagen and elastin
Over time, collagen and elastin fibres diminish in the dermis layer, which lessens support for the epidermis, causing skin to wrinkle.

Loss of fat
As we age, skin will start to sag as fat depletes in the hypodermis layer.

Is sunscreen really waterproof?
1 No sunscreen is truly waterproof. They can be water-resistant but will need to be re-applied every few hours. Even sweat can affect it!

Danger times
2 UV radiation is most intense between 10am to 2pm In Australia, sunburn can occur in less than 15 minutes on a fine January day. UV radiation is not related to temperature.

Peeling
3 Peeling is the body's way of ridding itself of damaged skin cells that might develop into cancers. Damaged skin cells self-destruct and peel off in sheets.

How we tan
4 Skin colour depends on a pigment called melanin which protects your skin by absorbing UV radiation and it darkens when doing so, leaving you with a sun tan.

Hidden dangers
5 On a cloudy day 30 to 50 per cent of the Sun's UV rays reach your skin, so it's still possible to burn. You may not feel the Sun's rays if it's windy, but they still cause damage.

DID YOU KNOW? *Romans developed crude mirrors by pouring boiling lead over the back of blown glass*

What are moles?

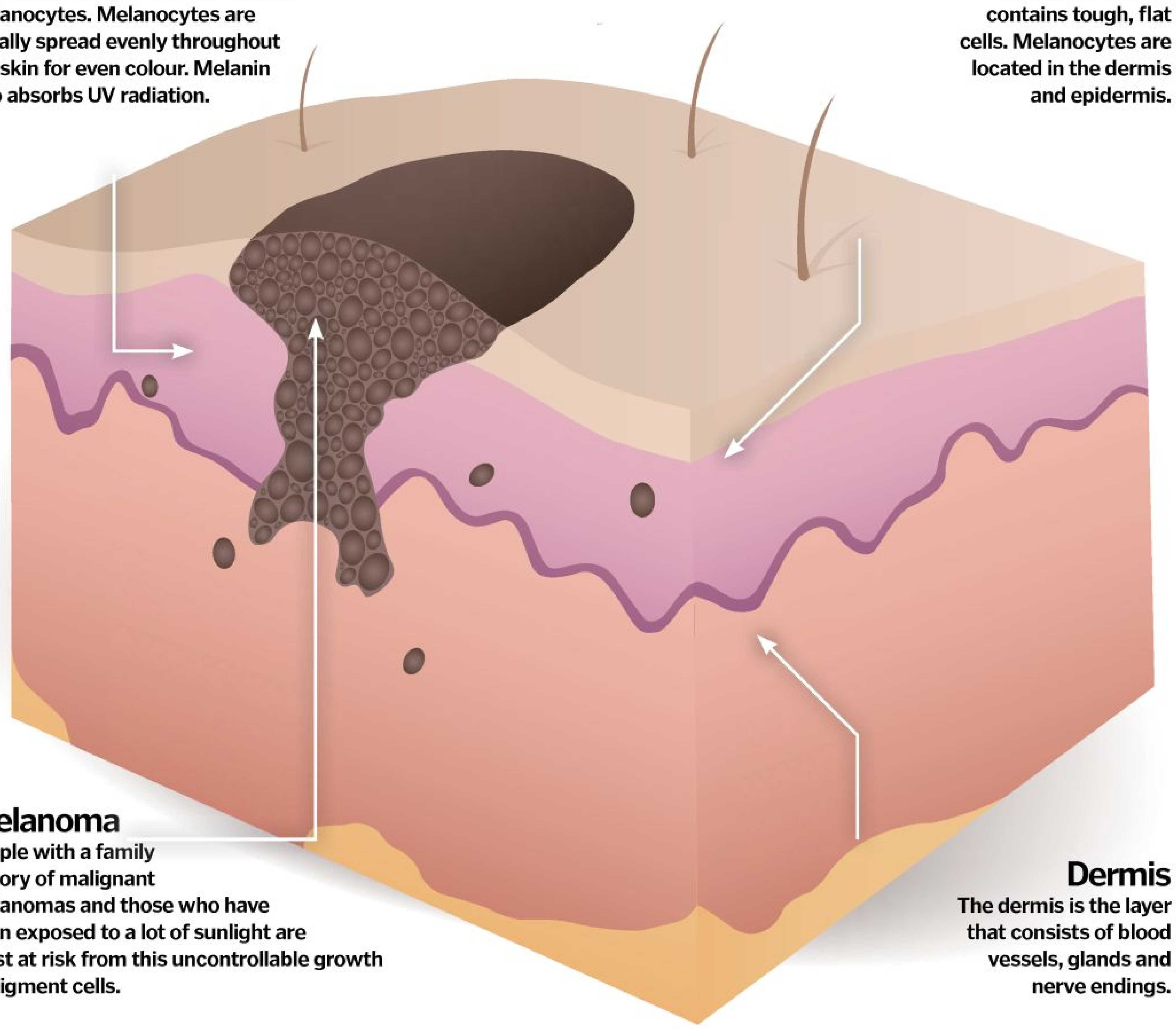
These small skin blemishes are common, but what are they and why must we keep a close eye on them?

A mole on the skin, or a melanocytic naevus, is an abnormal collection of the pigment cells called melanocytes. Some moles can be present at birth (congenital melanocytic naevi) but most develop spontaneously later in life, usually as a result of exposure to sunlight. Moles are often brown or black (pigmented naevi) and are usually round or oval, but they can be a variety of different shapes and sizes. Growth and change over time is quite normal.

Moles sound pretty unremarkable and are harmless in nature, and yet we must be vigilant if a new one appears on the skin or if an existing mole begins to change. A malignant melanoma is a rare kind of skin cancer that can occur in melanocytes. Although rare, malignant melanomas cause the majority of the deaths related to skin cancer. If you're particularly moley you're more susceptible to melanoma and should try to avoid too much sunlight.

Moles to watch are dysplastic naevi, which are large, irregularly shaped moles of mixed colouration. They often have paler, jagged edges with darker centres and tend to be accompanied by a lot of other moles on the body.

A malignant melanoma can spell trouble



At least he wore sunglasses...

Sunburn and its effects

We can often go red in the sun, but what causes this and what damage does it do to our skin?

Sunburn is caused by an overexposure to either sunlight or artificial UV rays. Sunburn doesn't occur every time the skin is exposed, indeed low-level exposure often causes tanning, a darkening of the skin caused by an increase in levels of melanin, a pigment already present in skin.

Burning is a reddening of the skin caused by groups of blood vessels expanding and breaking as blood rushes to the surface to attempt to heal the burn to living tissue. More severe sunburn can cause blistering of skin and often we see dehydration, dizziness and tiredness displayed alongside damage to the skin.

Skin damage caused by sunburn can sometimes cause non-malignant tumours and skin cancer to occur as the skin's DNA becomes so damaged it cannot repair itself properly. We can lessen the chances of this by not exposing our skin for long periods of time and using sun creams which give the skin extra protection.

DID YOU KNOW?

Australia has the highest rate of skin cancer due to the majority of individuals being of Northern European descent and the intense sun commonly seen across the continent.

"Each day the kidneys will filter 150-180 litres of blood"

Kidney function

How do your kidneys filter waste from the blood to keep you alive?

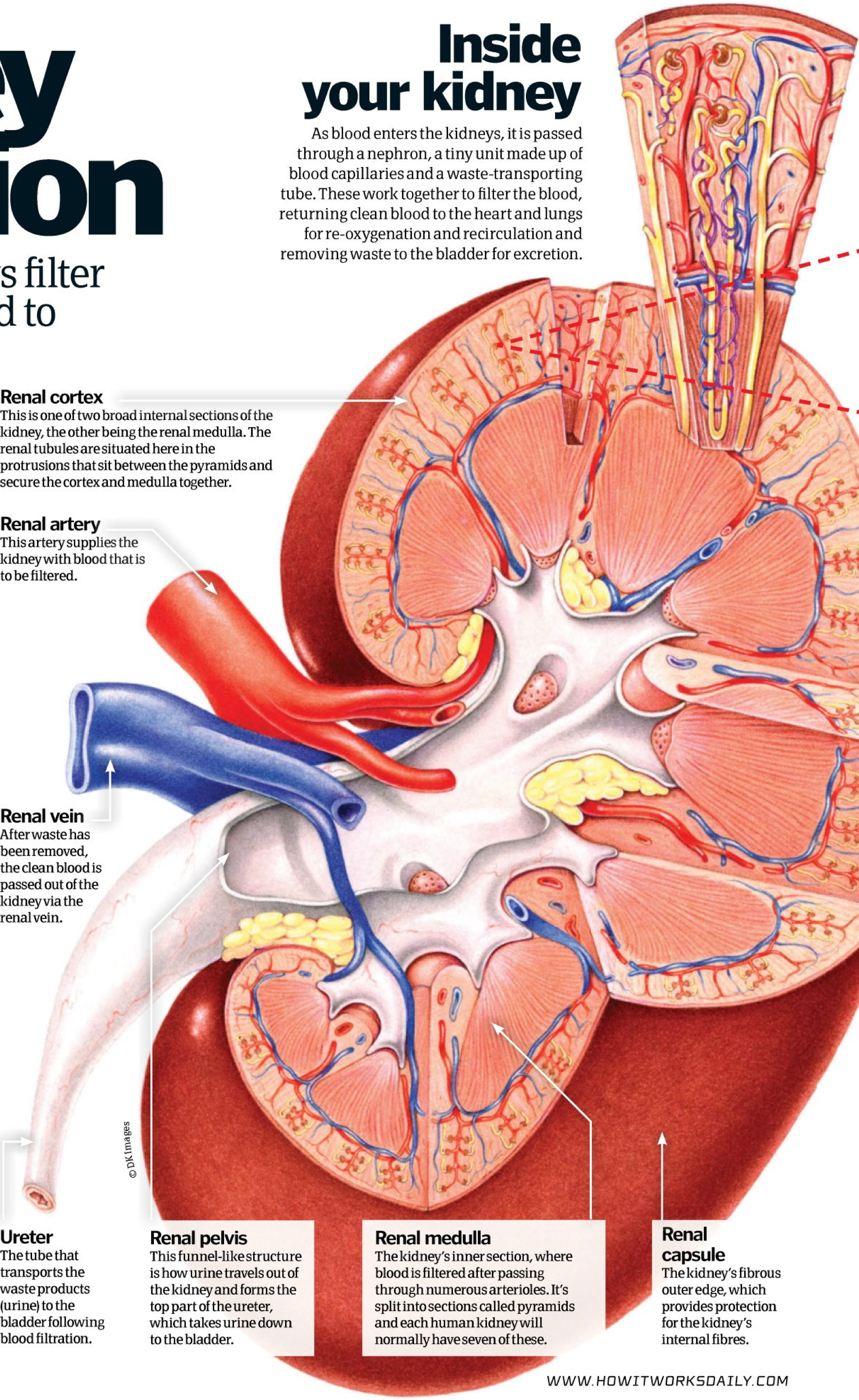
Kidneys are bean-shaped organs situated halfway down the back just under the ribcage, one on each side of the body, and weigh between 115 and 170 grams each, dependent on the individual's sex and size. The left kidney is commonly a little larger than the right and due to the effectiveness of these organs, individuals born with only one kidney can survive with little or no adverse health problems. Indeed, the body can operate normally with a 30-40 per cent decline in kidney function. This decline in function would rarely even be noticeable and shows just how effective the kidneys are at filtering out waste products as well as maintaining mineral levels and blood pressure throughout the body. The kidneys manage to control all of this by working with other organs and glands across the body such as the hypothalamus, which helps the kidneys determine and control water levels in the body.

Each day the kidneys will filter between 150 and 180 litres of blood, but only pass around two litres of waste down the ureters to the bladder for excretion. This waste product is primarily urea – a by-product of protein being broken down for energy – and water, and it's more commonly known as 'urine'. The kidneys filter the blood by passing it through a small filtering unit called a nephron. Each kidney has around a million of these, which are made up of a number of small blood capillaries, called glomerulus, and a urine-collecting tube called the renal tubule. The glomerulus sift the normal cells and proteins from the blood and then move the waste products into the renal tubule, which transports urine down into the bladder through the ureters.

Alongside this filtering process, the kidneys also release three crucial hormones (known as erythropoietin, renin and calcitriol) which encourage red blood cell production, aid regulation of blood pressure and aid bone development and mineral balance respectively.

Inside your kidney

As blood enters the kidneys, it is passed through a nephron, a tiny unit made up of blood capillaries and a waste-transporting tube. These work together to filter the blood, returning clean blood to the heart and lungs for re-oxygenation and recirculation and removing waste to the bladder for excretion.



Kidney fact

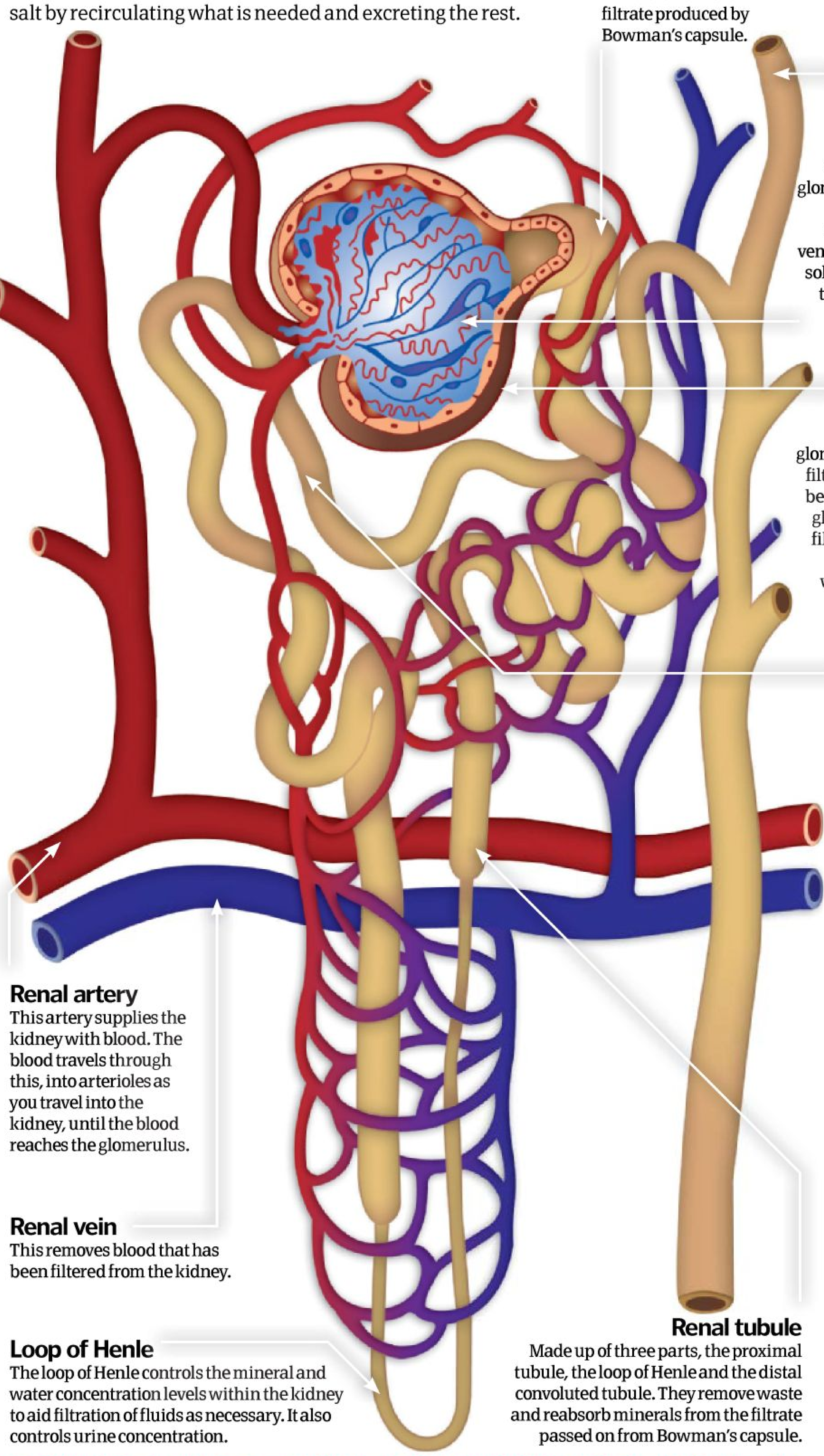
Two for the price of one

We are thought to have two kidneys because they are so crucial to our survival, the second is purely a 'back up'. Having two organs obviously increases our chances of survival and reproductive fitness.

DID YOU KNOW? Around 0.07% of the population are born with more than two kidneys

Nephrons – the filtration units of the kidney

Nephrons are the units which filter all blood that passes through the kidneys. There are around a million in each kidney, situated in the renal medulla's pyramid structures. As well as filtering waste, nephrons regulate water and mineral salt by recirculating what is needed and excreting the rest.



Proximal tubule
Links Bowman's capsule and the loop of Henle, and will selectively reabsorb minerals from the filtrate produced by Bowman's capsule.

Collecting duct system
Although not technically part of the nephron, this collects all waste product filtered by the nephrons and facilitates its removal from the kidneys.

Glomerulus
High pressure in the glomerulus, caused by it draining into an arteriole instead of a venule, forces fluids and soluble materials out of the capillary and into Bowman's capsule.

Bowman's capsule
Also known as the glomerular capsule, this filters the fluid that has been expelled from the glomerulus. Resulting filtrate is passed along the nephron and will eventually make up urine.

Distal convoluted tubule
Partly responsible for the regulation of minerals in the blood, linking to the collecting duct system. Unwanted minerals are excreted from the nephron.

Renal artery
This artery supplies the kidney with blood. The blood travels through this, into arterioles as you travel into the kidney, until the blood reaches the glomerulus.

Renal vein
This removes blood that has been filtered from the kidney.

Loop of Henle
The loop of Henle controls the mineral and water concentration levels within the kidney to aid filtration of fluids as necessary. It also controls urine concentration.

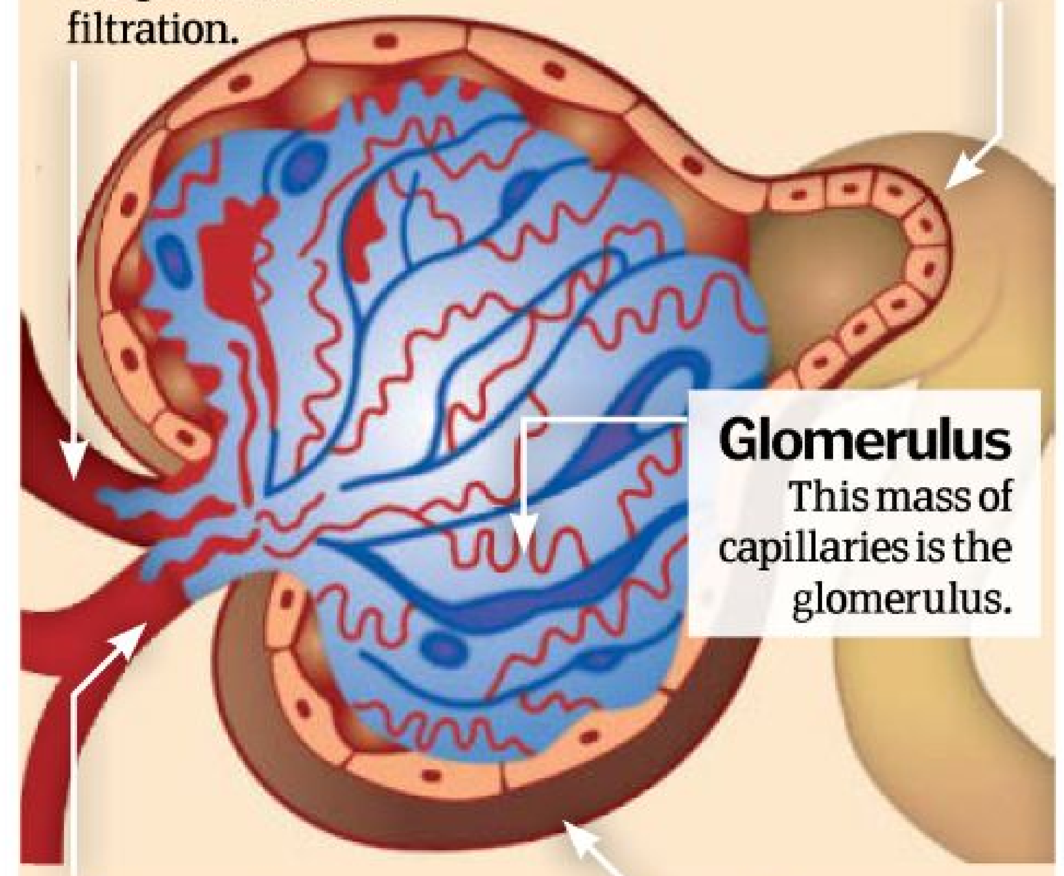
Renal tubule
Made up of three parts, the proximal tubule, the loop of Henle and the distal convoluted tubule. They remove waste and reabsorb minerals from the filtrate passed on from Bowman's capsule.

The glomerulus

This group of capillaries is the first step of filtration and a crucial aspect of a nephron. As blood enters the kidneys via the renal artery, it is passed down through a series of arterioles which eventually lead to the glomerulus. This is unusual, as instead of draining into a venule (which would lead back to a vein) it drains back into an arteriole, which creates much higher pressure than normally seen in capillaries, which in turn forces soluble materials and fluids out of the capillaries. This process is known as ultrafiltration and is the first step in filtration of the blood. These then pass through the Bowman's capsule (also know as the glomerular capsule) for further filtration.

Afferent arteriole
This arteriole supplies the blood to the glomerulus for filtration.

Proximal tubule
Where reabsorption of minerals from the filtrate from Bowman's capsule will occur.



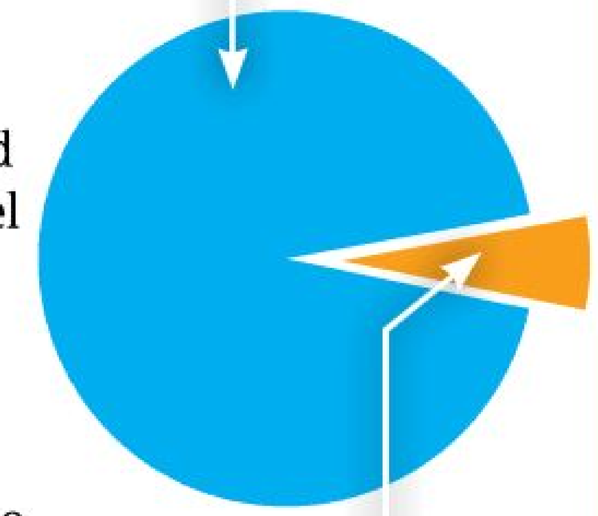
Glomerulus
This mass of capillaries is the glomerulus.

Efferent arteriole
This arteriole is how blood leaves the glomerulus following ultrafiltration.

Bowman's capsule
This is the surrounding capsule that will filter the filtrate produced by the glomerulus.

What is urine and what is it made of?

Urine is made up of a range of organic compounds such as proteins and hormones, inorganic salts and numerous metabolites. These by-products are often rich in nitrogen and need to be removed from the blood stream through urination. The pH-level of urine is typically around neutral (pH7) but varies depending on diet, hydration levels and physical fitness. The colour of urine is also determined by these factors, with dark-yellow urine indicating dehydration and greenish urine being indicative of excessive asparagus consumption.



“The kidney is the most transplanted organ”

The kidneys are the body’s natural filters. You can survive on just one, but when that fails you may need a transplant

Kidney transplants

Transplanting organs is a complex process, although it can give a new lease of life to recipients. The kidney is the most frequently transplanted organ, both in the UK and around the world. However, there is a discrepancy between the number of patients waiting for a transplant and the number of available organs; only around one third of those waiting per year receive their transplant. The number of patients registered for a kidney transplant increases each year, and has risen by 50 per cent since 2000.

Kidney transplants come from two main sources: the living and the recently deceased. If a healthy, compatible family member is willing to donate a kidney, they can survive with just one remaining kidney. In other cases, someone else’s tragedy is someone else’s fortune. For those who are declared brain-dead, the beating heart will keep the kidneys perfused until they are ready to be removed. In some patients, the ventilator will be switched off and it’s a race against time to harvest organs. Either way, consent from the family is needed, even at such an emotional and pressurised time.

When a suitable organ becomes available, it is matched via a national register to a suitable recipient. A ‘retrieval’ team from a central transplant unit (of which there are 20 based around the UK) will go to whichever hospital the donor is in. They will remove the organs, while the recipient is being prepared in the base hospital. During the tricky operation, the new kidney is ‘plumbed’ into the pelvis, leaving the old, non-functioning ones in-situ.

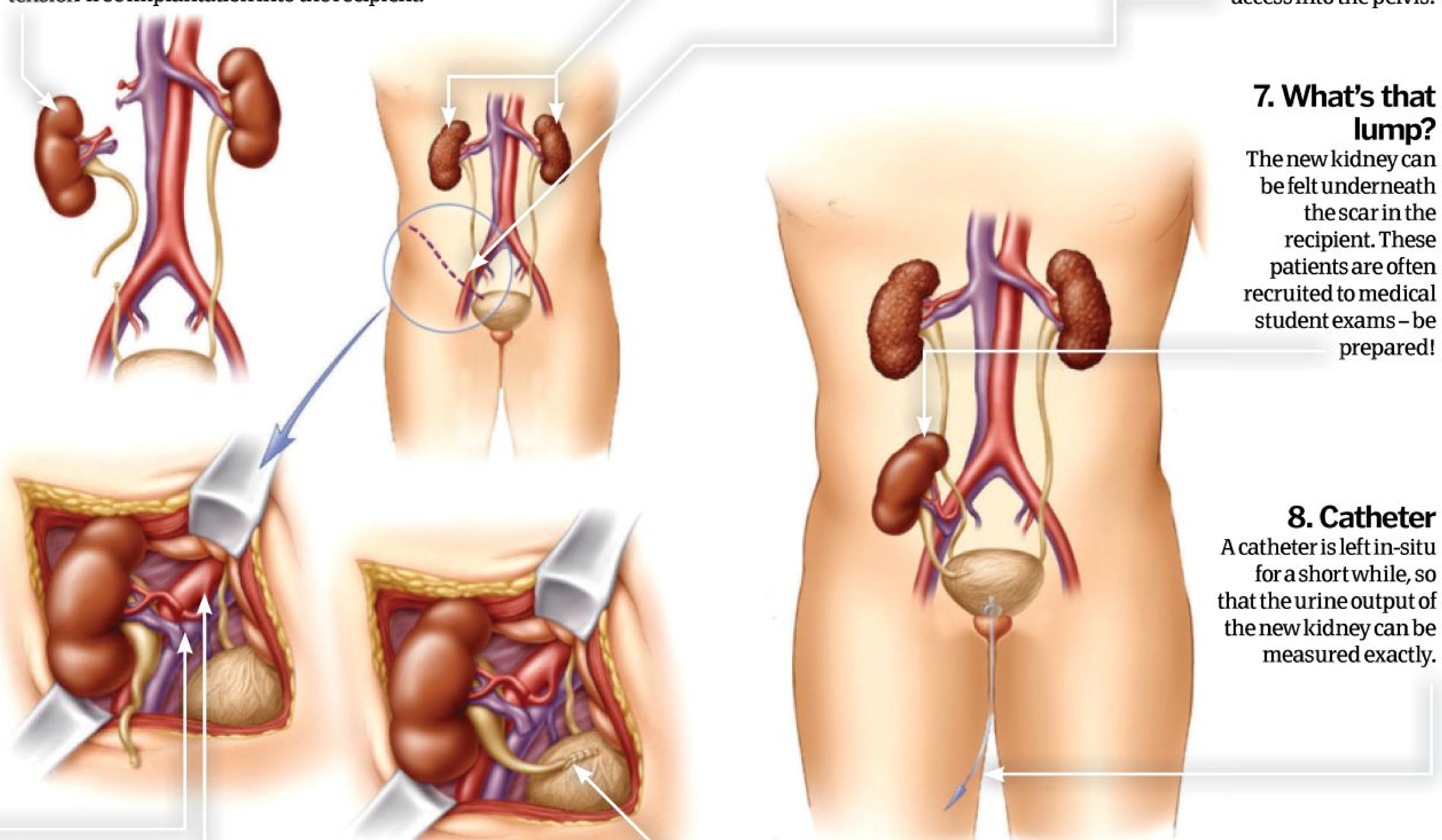
How to perform a kidney transplant

Transplanting a kidney is a case of careful and clever plumbing. The first step is to harvest the donor kidney, and then it’s a dash to transplant the new kidney into the recipient. When the brain-dead donor is transferred to the operating theatre for organ harvest, they are treated with the same care and respect as if they were still alive. When consent has been given for multiple organ harvest, a cut is made from the top of the chest to the bottom of the pelvis. The heart and lungs are retrieved first, followed by the abdominal organs.

1. The donor
The donor kidney is harvested, including enough length of artery, vein and ureter (which carries urine to the bladder) to allow tension-free implantation into the recipient.

2. Out with the old?
As long as there’s no question of cancer, the original kidneys are left in place.

3. Into the pelvis
An incision is made in the lower part of the abdomen to gain access into the pelvis.



7. What’s that lump?
The new kidney can be felt underneath the scar in the recipient. These patients are often recruited to medical student exams – be prepared!

8. Catheter
A catheter is left in-situ for a short while, so that the urine output of the new kidney can be measured exactly.

5. Plumbing it in
The renal artery and vein are connected to the corresponding iliac artery and vein in the recipient’s body. Holes (arteriotomies) are created in the main arteries, and the kidney’s vessels are anastomosed (a surgical join between two tubes using sutures).

4. Make space!
The surgeon will create space in the pelvis, and identify the large vessels which run from the heart to the leg (the iliac arteries and veins). The new kidney’s vessels will be connected to these.

6. The final link
The ureter, which drains urine from the kidney, is connected to the bladder. This allows the kidney to function in the same way as one of the original kidneys.

5 TOP FACTS
TRANSPLANTS

Pioneers
1 The very first kidney transplant to take place in the UK was performed in Edinburgh, Scotland, back in 1960, where a surgeon transplanted a kidney from a 49-year-old into his twin brother.

The 'organ gap'
2 Around 7,000 people in the United Kingdom last year were waiting for organ transplants, but only around 2,300 kidney transplants actually took place.

Which other organs?
3 Organs that can be transplanted include kidneys, livers, hearts, lungs, the pancreas and intestines. Transplantable tissues include bones, heart valves, skin and corneas.

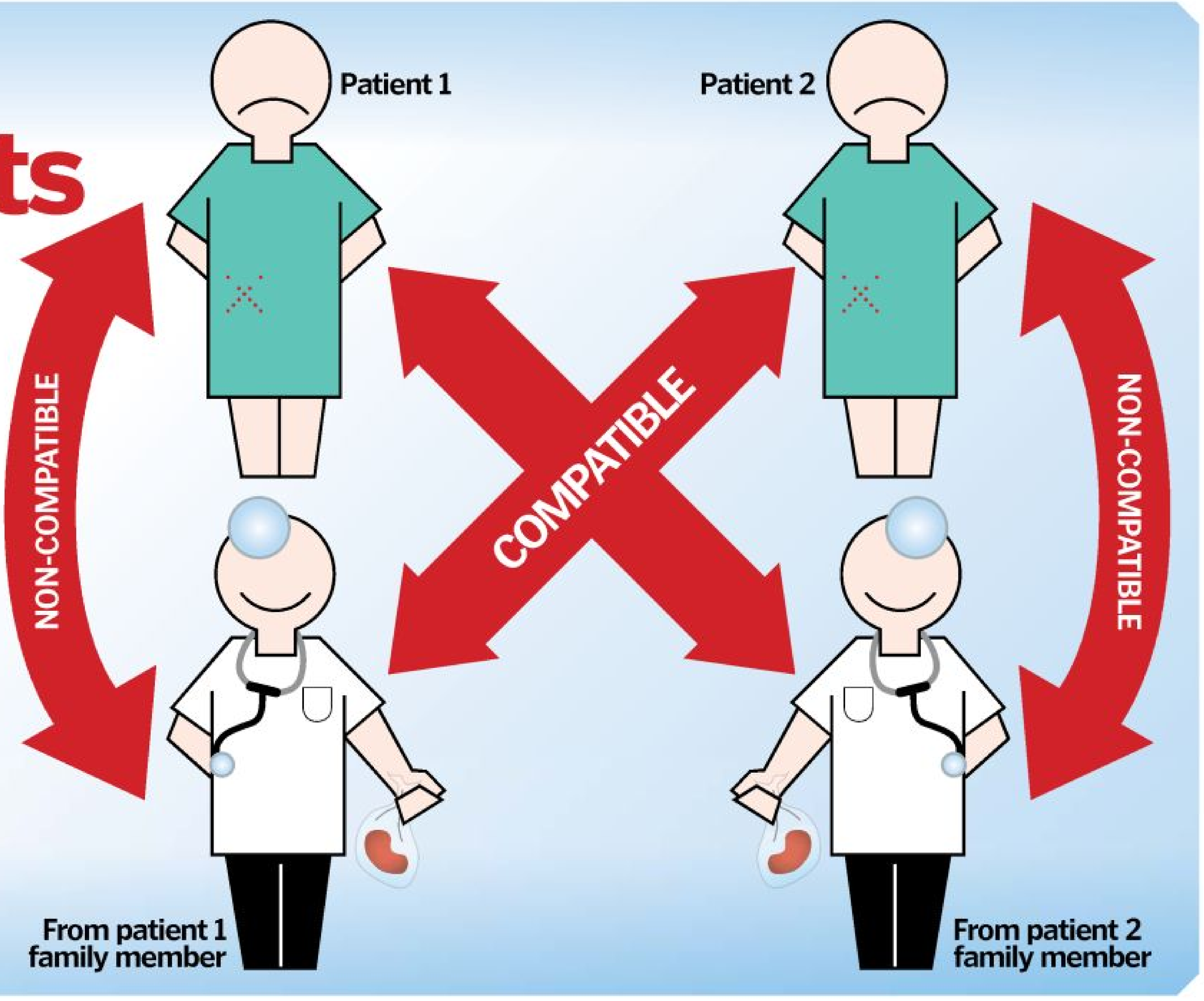
Through the keyhole
4 When removing a kidney from a living donor, the most modern centres use keyhole surgery (laparoscopy) to do it – this leads to smaller scars, less pain and faster recovery times.

Do something about it
5 You can register to become an organ donor at http://www.organdonation.nhs.uk/ – don't forget to talk to your loved ones about it.

DID YOU KNOW? *The human heart is not heart shaped – the popular heart shape was widely used on T-shirts in the 1970s*

Domino transplants

Patient 1 needs a new kidney but their family member isn't compatible. Patient 2 also needs a kidney and has an incompatible family member as well. However, patient 2's relation is compatible with patient 1 and vice versa. The surgeon arranges a swap – a 'paired' transplant. A longer line of patients and family members swapping compatible kidneys can be arranged – a 'daisy-chain' transplant. A 'good Samaritan' donor, who isn't related to any of the recipients, can start the process. This first recipient's family member will subsequently donate to someone else – a 'domino' transplant effect which can go on for several cycles.



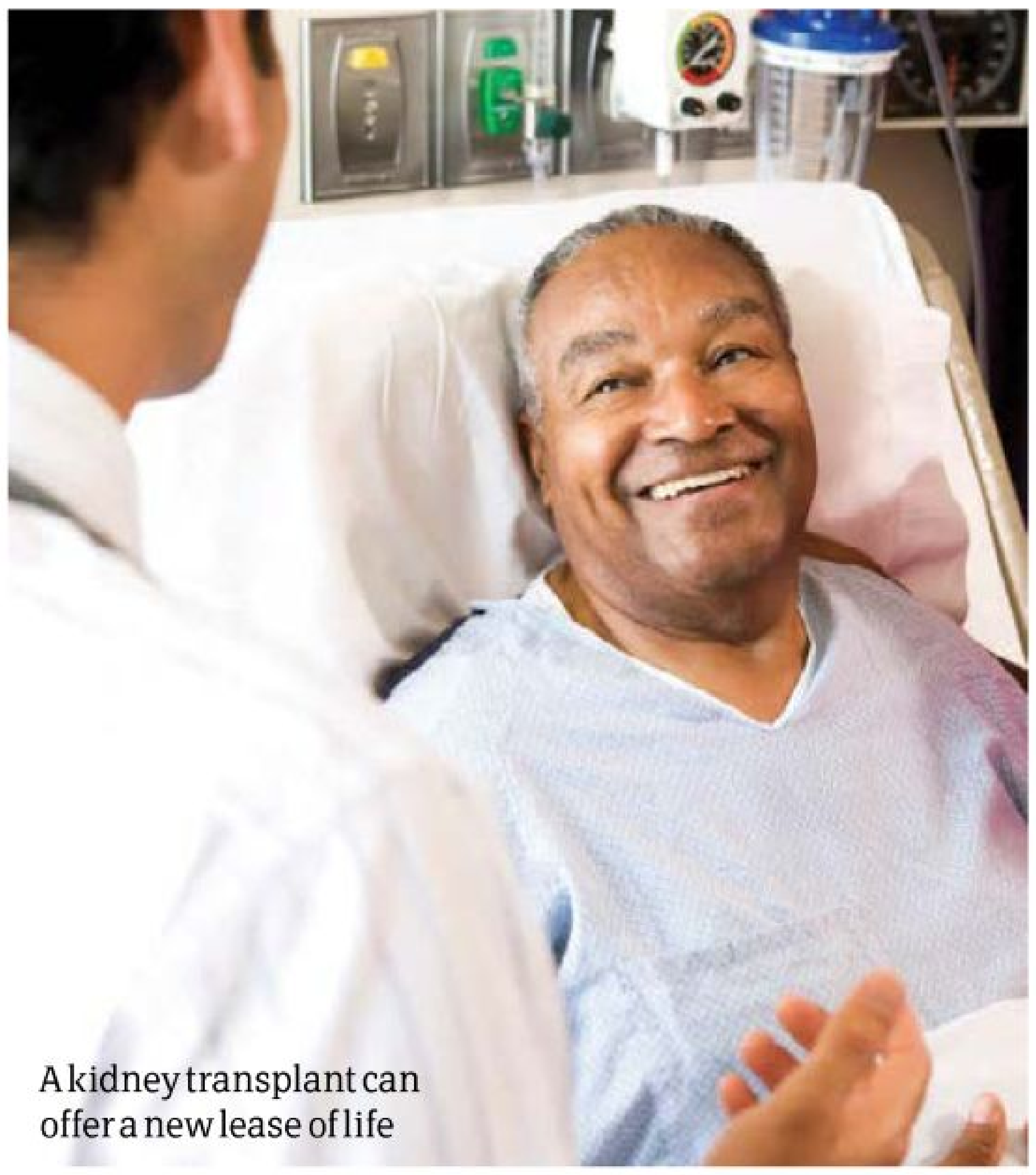

Time is always of the essence

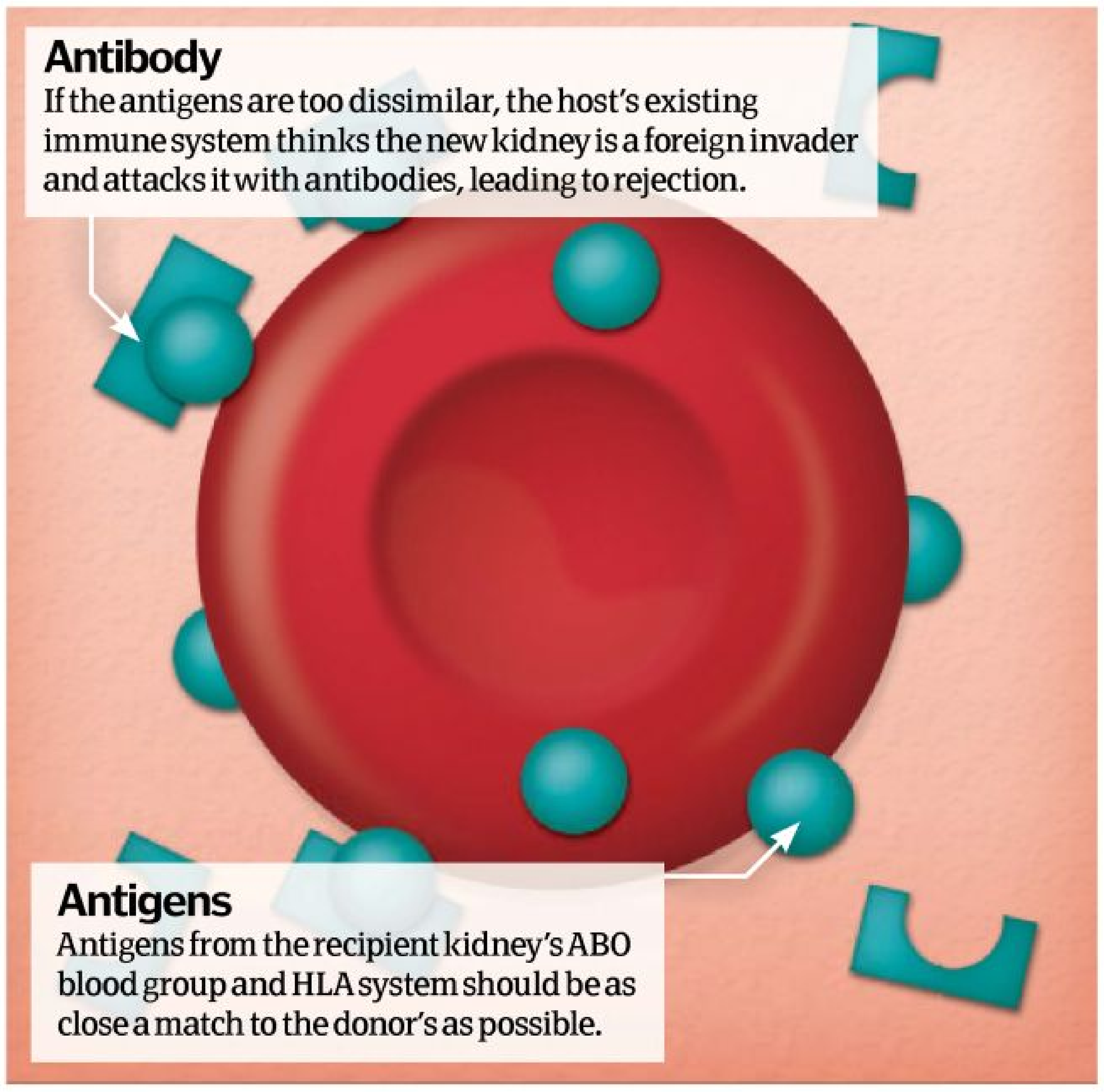
©Science Photo Library

Who is suitable?

Of the several million people in the UK with kidney disease, only around 50,000 will develop end-stage renal failure (ESRF). For these people, dialysis or kidney transplantation are the only options. Kidney damage from diabetes is the most common cause of transplantation. Other causes include damage from high blood pressure, chronic kidney scarring (chronic pyelonephritis) and polycystic kidney disease (the normal kidney tissue is replaced with multiple cysts); many other less common causes exist.

Patients must be selected carefully due to the scarcity of organs. Those with widespread cancer, severely calcified arteries, persistent substance abuse and unstable mental problems mean that transplants are likely to fail and so these patients are unsuitable to receive a precious kidney transplant.


A kidney transplant can offer a new lease of life



When things go wrong…

Kidneys need to be carefully matched to suitable donors, or rejection of the new organ will set in fast. Rejection occurs when the host body's natural antibodies think the new tissue is a foreign invader and attacks; careful pre-operative matching helps limit the degree of this attack. The most important match is via the ABO blood group type – the blood group must match or rejection is fast and aggressive. Next, the body's HLA (human leukocyte antigen) system should be a close a match as possible, although it doesn't need to be perfect. Incorrect matches here can lead to rejection over longer periods of time. After the operation, patients are started on anti-rejection medicines which suppress the host's immune system (immunosuppressants such as Tacrolimus, Azathioprine or Prednisolone). Patients are monitored for the rest of their lives for signs of rejection. These immunosuppressants aren't without their risks – since they suppress the body's natural defences, the risks of infections and cancers are higher.

Pack carefully!

The transport of harvested organs is time critical – the sooner the surgeon can put them into the recipient the better. As soon as blood stops flowing to the harvested tissue, the lack of oxygen damages these cells, which is called ischaemia. The retrieval team have a few tricks up their sleeves to maximise the viability of the precious cargo they carry.

In the operating theatre, just before they remove the harvested kidney, it is flushed clean of blood with a special cold, nutrient-rich solution. Once removed, it is quickly put in a sterile container with ice. The most modern technique is to use a cold perfusion machine instead of ice, which pumps a cooled solution through the kidney and improves its lasting power. While hearts and lungs can only last around four hours, kidneys can last 24-48 hours. Transfer of the affected organ is done via the fastest method possible; this often involves using helicopters or police escorts.

All of these methods prolong the preservation time of the kidney, although once 'plugged' back in, it can take a few days for the kidney to start working properly (especially if harvested from a non-heart-beating donor).

“It is the second most complex organ after the brain”

How the liver v

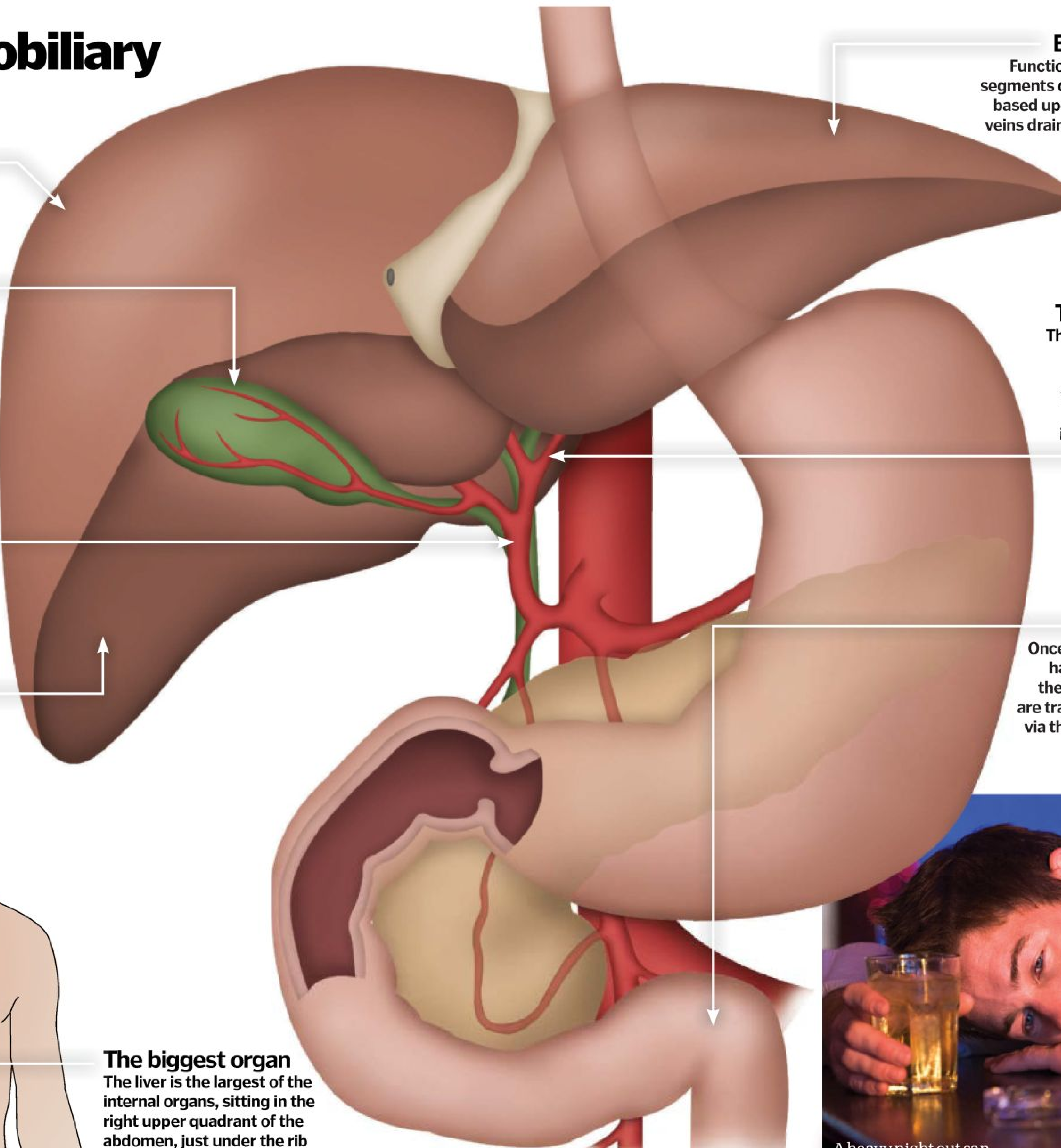
The human liver is the ultimate multitasker – it performs many different functions all at the same time without you even asking

The liver is the largest internal organ in the human body and amazingly has over 500 different functions. In fact, it is the second most complex organ after the brain and is intrinsically involved in almost every aspect of the body’s metabolic processes. The liver’s main functions are energy production, removal of harmful substances and the production of crucial proteins. These tasks are carried out within liver cells, called hepatocytes, which sit in complex arrangements to maximise efficiency.

The liver is the body’s main powerhouse, producing and storing glucose as a key energy source. It is also responsible for breaking down complex fat molecules and building them up into cholesterol and triglycerides, which the body needs but in excess are bad. The liver makes many complex proteins, including clotting factors which are vital in arresting bleeding. Bile, which helps digest fat in the intestines, is produced in the liver and stored in the adjacent gallbladder.

The liver also plays a key role in detoxifying the blood. Waste products, toxins and drugs are processed here into

The hepatobiliary region



Two halves
The liver is anatomically split into two halves: left and right. There are four lobes, and the right lobe is the largest.

The gallbladder
The gallbladder and liver are intimately related. Bile, which helps digest fat, is produced in the liver and stored in the gallbladder.

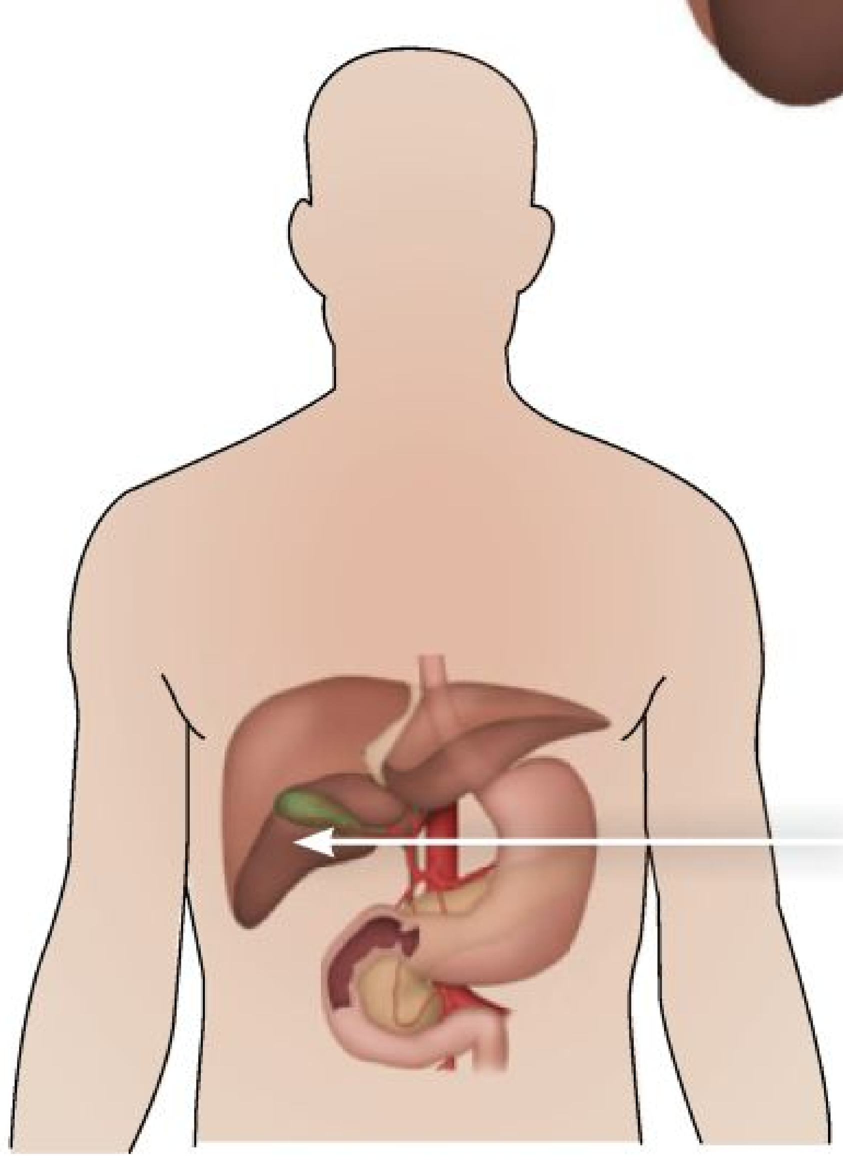
The common bile duct
This duct is small, but vital in the human body. It carries bile from the liver and gallbladder into the duodenum where it helps digest fat.

Feel your liver
Take a deep breath in and feel just under the right lower edge of your ribs – in some people the lower edge of the liver can be felt.

Eight segments
Functionally, there are eight segments of the liver, which are based upon the distribution of veins draining these segments.

The portal triad
The common bile duct, hepatic artery and hepatic portal vein form the portal triad, which are the vital inflows and outflows for this liver.

Digestion
Once nutrients from food have been absorbed in the small intestine, they are transported to the liver via the hepatic portal vein (not shown here) for energy production.



The biggest organ
The liver is the largest of the internal organs, sitting in the right upper quadrant of the abdomen, just under the rib cage and attached to the underside of the diaphragm.

A heavy night out can take its toll on your liver

Ice cold liver
1 Polar bear liver is an incredibly rich source of vitamin A – so much so that Arctic explorers have actually died from eating it, as it can cause vitamin A poisoning.

Liver transplants
2 In the UK 600-700 liver transplants are performed each year. The donor liver can be preserved in a solution for up to 24 hours before it is transplanted.

Maximising numbers
3 Ways around the shortage of donor livers include splitting an adult liver in half and giving it to two children, and live-donor transplantation (a portion of a relative's liver is transplanted).

Largest organ in the body
4 The liver is the largest internal organ in the human body and in most animals' bodies too. It typically has the same shape as a human's, except in snakes where it is elongated.

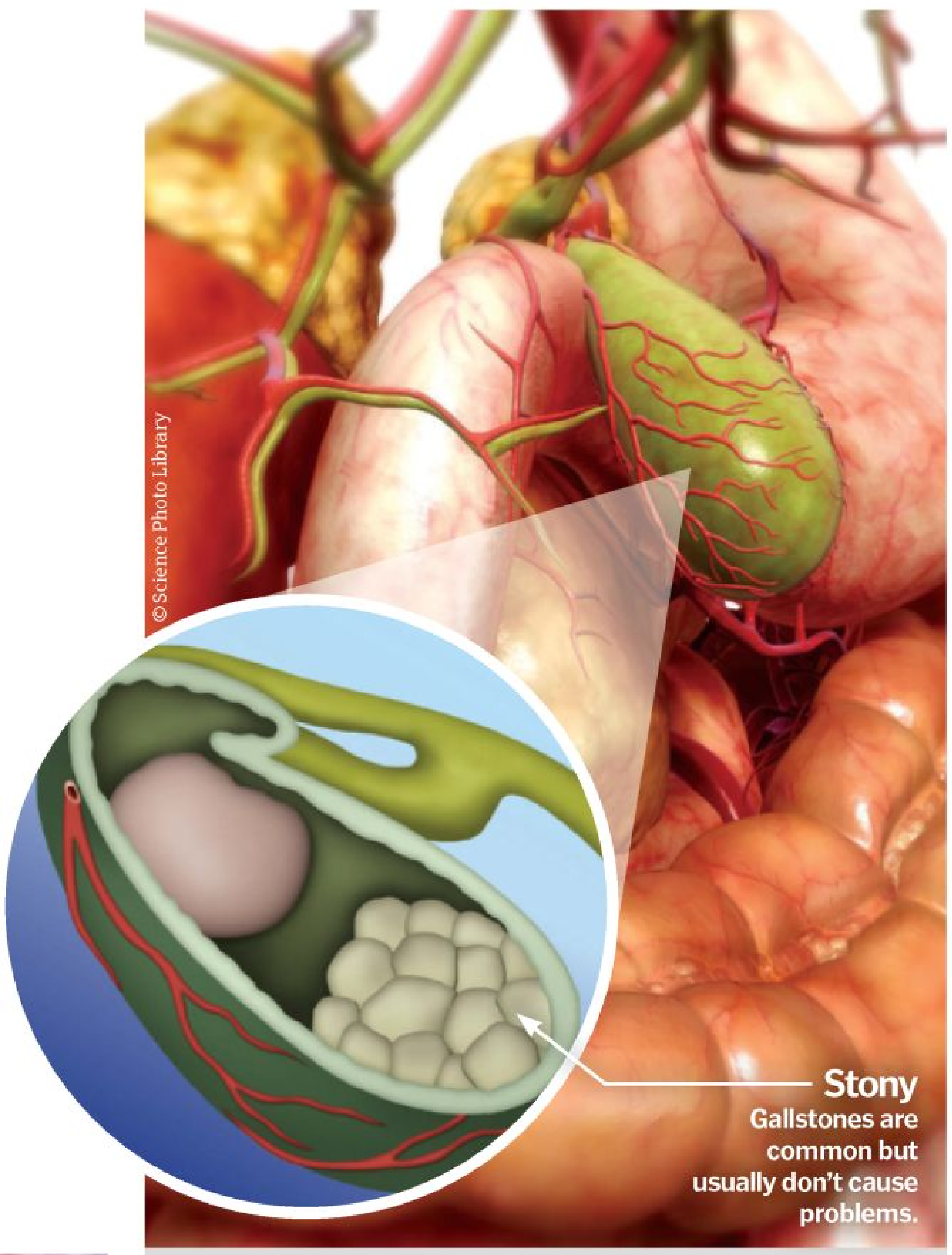
Greek mythology
5 Wise Titan Prometheus was chained for eternity to a rock in the Caucasus, where an eagle would eat at his liver and each day the liver would be renewed!

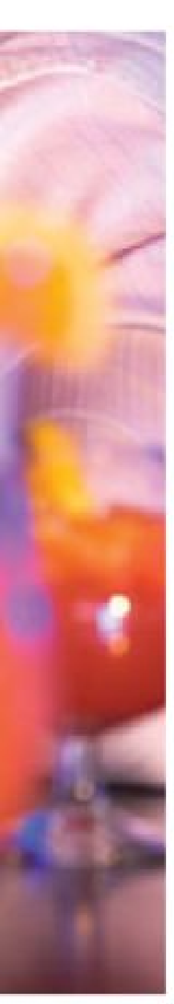
DID YOU KNOW? *The human heart is not heart shaped – the popular heart shape was widely used on T-shirts in the 1970s*

works

forms which are easier for the rest of the body to use or excrete. The liver also breaks down old bloods cells, produces antibodies to fight infection and recycles hormones such as adrenaline. Numerous essential vitamins and minerals are stored in the liver: vitamins A, D, E and K, iron and copper.

Such a complex organ is also unfortunately prone to diseases. Cancers (most often metastatic from other sources), infections (hepatitis) and cirrhosis (a form of fibrosis often caused by excess alcohol consumption) are just some of those which can affect the liver.





The gallbladder

Bile, a dark green slimy liquid, is produced in the hepatocytes and helps to digest fat. It is stored in a reservoir which sits on the under-surface of the liver, to be used when needed. This reservoir is called the gallbladder. Stones can form in the gallbladder (gallstones) and are very common, although most don't cause problems. In 2009, just under 60,000 gallbladders were removed from patients within the NHS making it one of the most common operations performed; over 90 per cent of these are removed via keyhole surgery. Most patients do very well without their gallbladder and don't notice any changes at all.

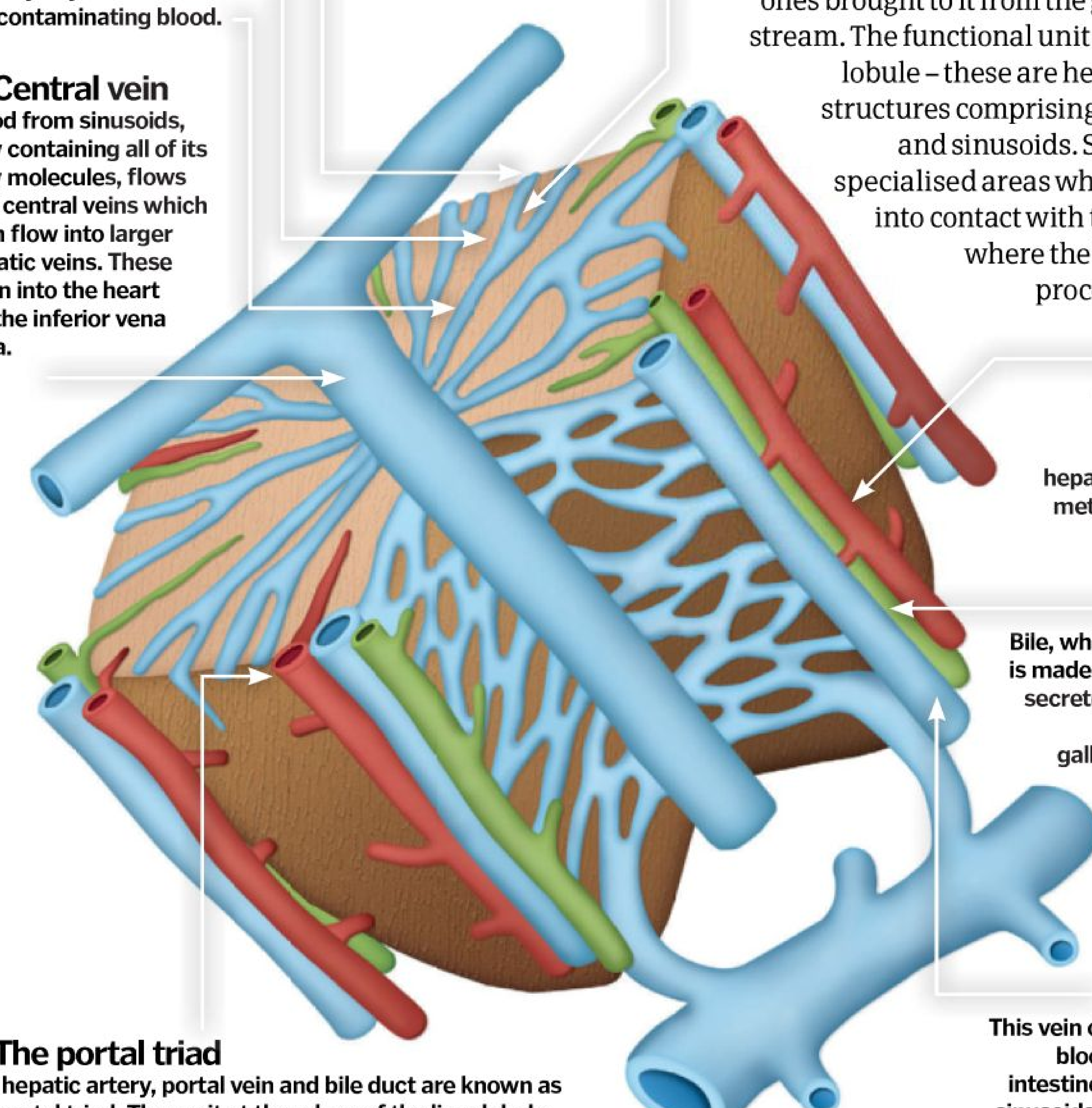
A high demand organ

The liver deals with a massive amount of blood. It is unique because it has two blood supplies. 75 per cent of this comes directly from the intestines (via the hepatic portal vein) which carries nutrients from digestion, which the liver processes and turns into energy. The rest comes from the heart, via the hepatic artery (which branches from the aorta), carrying oxygen which the liver needs to produce this energy. The blood flows in tiny passages inbetween the liver cells where the many metabolic functions occur. The blood then leaves the liver via the hepatic veins to flow into the biggest vein in the body – the inferior vena cava.

Liver lobules

The functional unit which performs the liver's tasks

The liver is considered a 'chemical factory,' as it forms large complex molecules from smaller ones brought to it from the gut via the blood stream. The functional unit of the liver is the lobule – these are hexagonal-shaped structures comprising of blood vessels and sinusoids. Sinusoids are the specialised areas where blood comes into contact with the hepatocytes, where the liver's biological processes take place.



> "The cells are all in contact with capillaries, so hormones can be fed directly into the bloodstream"

How the pancreas works

Learn how the workhorse of the digestive system helps to break down food and control our blood sugar levels

The pancreas is a pivotal organ within the digestive system. It sits inside the abdomen, behind the stomach and the large bowel, adjacent to the spleen. In humans, it has a head, neck, body and tail. It is connected to the first section of the small intestine, the duodenum, by the pancreatic duct, and to the bloodstream via a rich network of vessels. The function of the pancreas is best considered by thinking about the two types of cell it contains: endocrine and exocrine.

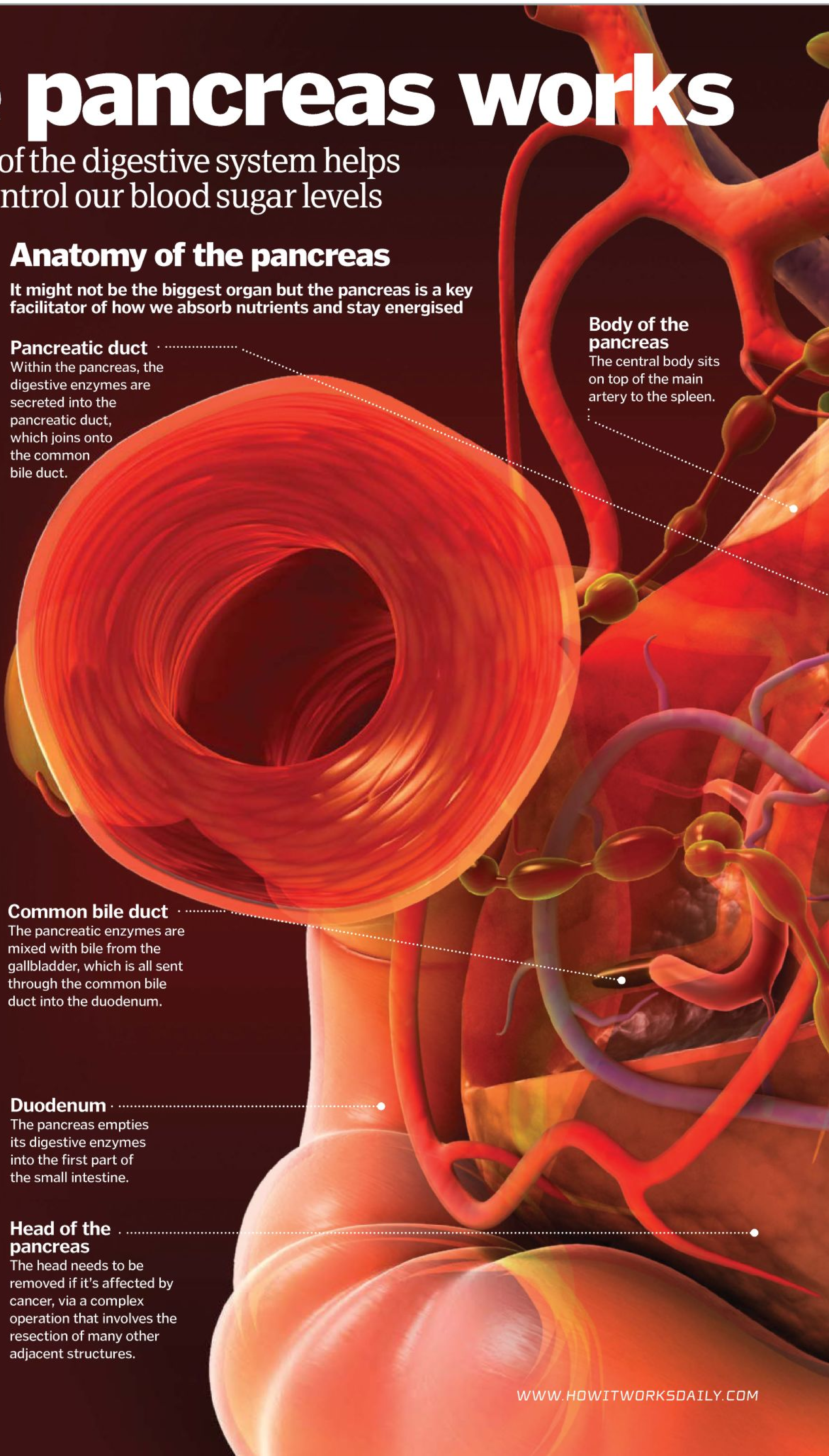
The endocrine pancreas is made up of clusters of cells called islets of Langerhans, which in total contain approximately 1 million cells and are responsible for producing hormones. These cells include alpha cells, which secrete glucagon, and beta cells which generate insulin. These two hormones have opposite effects on blood sugar levels throughout the body: glucagon increases glucose levels, while insulin decreases them.

The cells here are all in contact with capillaries, so hormones which are produced can be fed directly into the bloodstream. Insulin secretion is under the control of a negative-feedback loop; high blood sugar leads to insulin secretion, which then lowers blood sugar with subsequent suppression of insulin. Disorders of these cells (and thus alterations of hormone levels) can lead to many conditions, including diabetes. The islets of Langerhans are also responsible for producing other hormones, like somatostatin, which governs nutrient absorption among other things.

The exocrine pancreas, meanwhile, is responsible for secreting digestive enzymes. Cells are arranged in clusters called acini, which flow into the central pancreatic duct. This leads into the duodenum – part of the small bowel – to come into contact with and aid in the digestion of food. The enzymes secreted include proteases (to digest protein), lipases (for fat) and amylase (for sugar/starch). Secretion of these enzymes is controlled by a series of hormones (gastrin, cholecystokinin and secretin), which are released from the stomach and duodenum in response to the stretch from the presence of food.

Anatomy of the pancreas

It might not be the biggest organ but the pancreas is a key facilitator of how we absorb nutrients and stay energised



KEY DATES
PANCREATIC PAST

336 BCE The Greek anatomist who will first discover the pancreas – Herophilus – is born.

1st century CE The name 'pancreas' is given, meaning 'all flesh', as it's believed to serve solely as a cushioning, protective fat pad.

1642 The pancreatic duct is found in Padua, Italy. It is named after its discoverer: the duct of Wirsung.

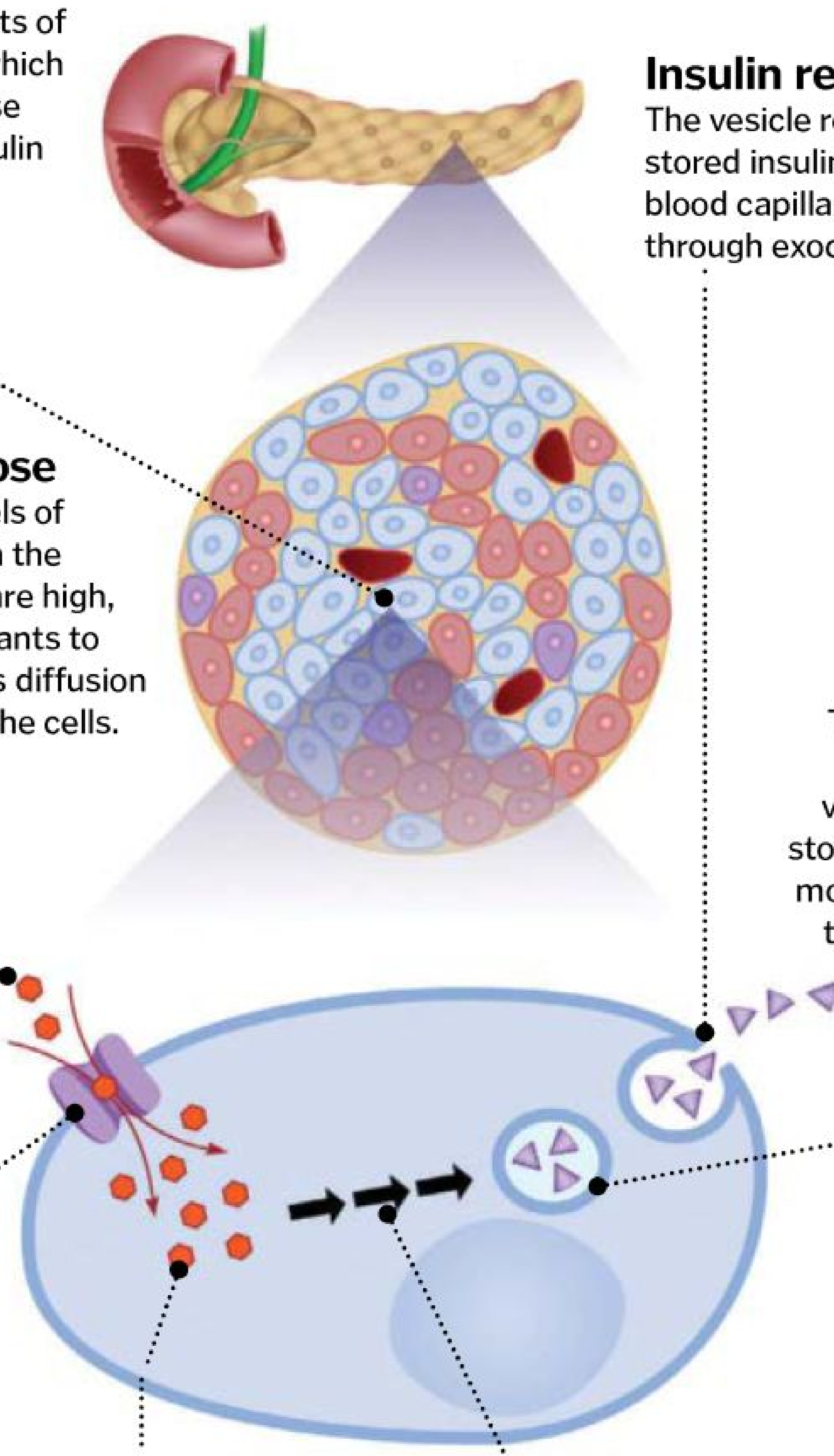
1889 German scientists remove the pancreas in a dog and induce diabetes, proving an irrefutable link.

1966 The first modern human pancreatic transplant is performed in the USA on a 28-year-old female patient.

DID YOU KNOW? *In the UK, 80 per cent of acute pancreatitis cases are caused by gallstones or excessive alcohol ingestion*

What brings on diabetes?

Diabetes is a condition where a person has higher blood sugar than normal. It is either caused by a failure of the pancreas to produce insulin (ie type 1, or insulin-dependent diabetes mellitus), or resistance of the body's cells to insulin present in the circulation (ie type 2, or non-insulin-dependent diabetes mellitus). There are also other disorders of the pancreas. Inflammation of the organ (ie acute pancreatitis) causes severe pain in the upper abdomen, forcing most people to attend the emergency department as it can be life threatening. In contrast, cancer of the pancreas causes gradually worsening pain which can often be mistaken for other ailments.



Does the pancreas vary in humans and animals?

Every vertebrate animal has a pancreas of some form, meaning they are all susceptible to diabetes too. The arrangement, however, varies from creature to creature. In humans, the pancreas is most often a single structure that sits at the back of the abdomen. In other animals, the arrangement varies from two or three masses of tissue scattered around the abdomen, to tissue interspersed within the connective tissue between the bowels, to small collections of tissue within the bowel mucosal wall itself. One of the other key differences is the number of ducts that connect the pancreas to the bowel. In most humans there's only one duct, but occasionally there may be two or three – and sometimes even more. In other animals, the number is much more variable. However, the function is largely similar, where the pancreas secretes digestive enzymes and hormones to control blood sugar levels.

Inside the human stomach

Discover how this amazing digestive organ stretches, churns and holds corrosive acid to break down our food, all without getting damaged

The stomach's major role is as a reservoir for food; it allows large meals to be consumed in one sitting before being gradually emptied into the small intestine. A combination of acid, protein-digesting enzymes and vigorous churning action breaks the stomach contents down into an easier-to-process liquid form, preparing food for absorption in the bowels.

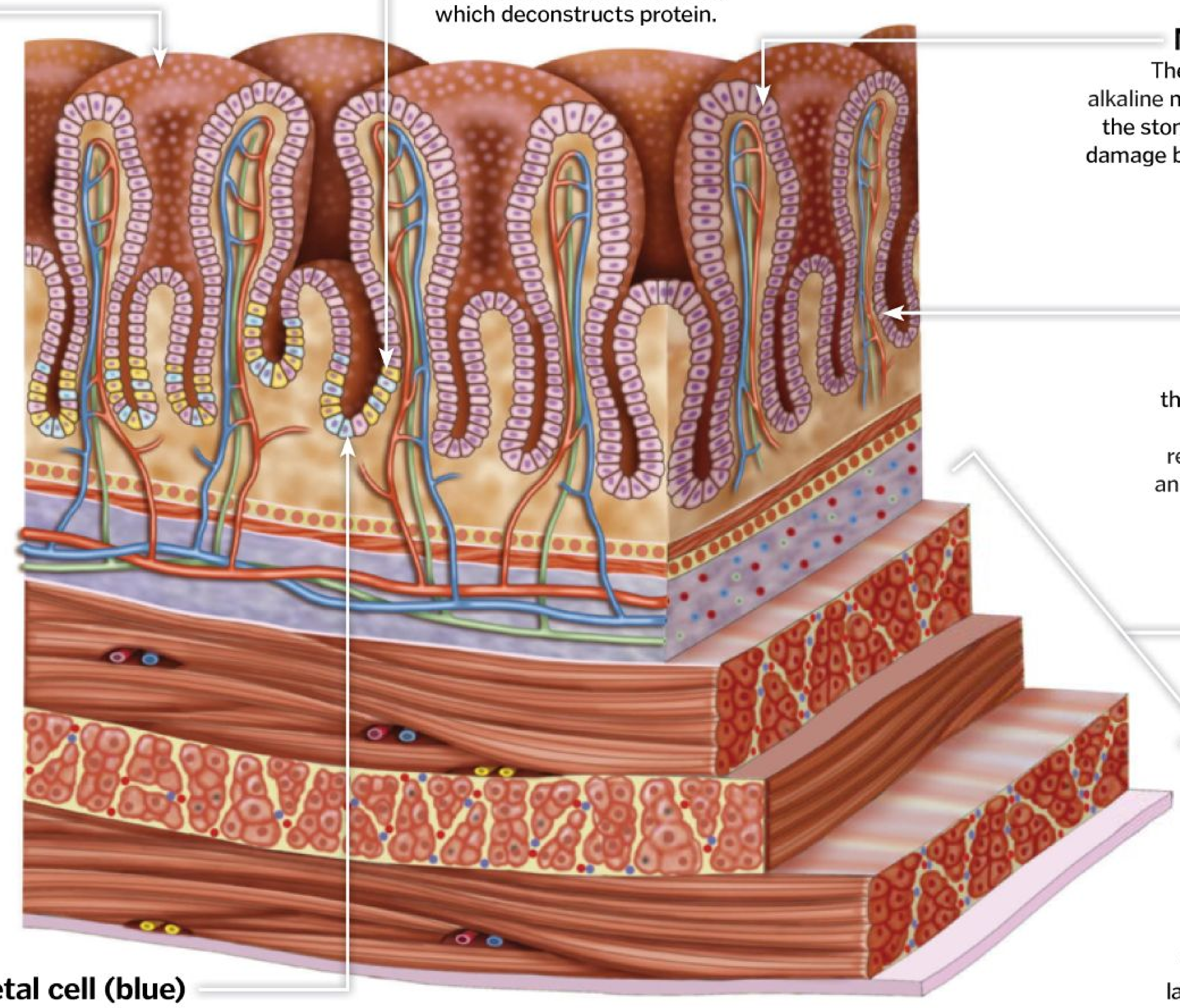
In its resting state, the stomach is contracted and the internal surface of the organ folds into characteristic ridges, or rugae. When we start eating, however, the stomach begins to distend; the rugae flatten, allowing the stomach to expand, and the outer muscles relax. The stomach can accommodate about a litre (1.8 pints) of food without discomfort.

The expansion of the stomach activates stretch receptors, which trigger nerve signalling that results in increased acid production and powerful muscle contractions to mix and churn the contents. Gastric acid causes proteins in the food to unravel, allowing access by the enzyme pepsin, which breaks down protein. The presence of partially digested proteins stimulates enteroendocrine cells (G-cells) to make the hormone gastrin, which encourages even more acid production.

The stomach empties its contents into the small intestine through the pyloric sphincter. Liquids pass through the sphincter easily, but solids must be smaller than one to two millimetres (0.04-0.08 inches) in diameter before they will fit. Anything larger is 'refluxed' backwards into the main chamber for further churning and enzymatic breakdown. It takes about two hours for half a meal to pass into the small intestine and the process is generally complete within four to five hours.

Lining under the microscope

The stomach is much more than just a storage bag. Take a look at its complex microanatomy now…



Gastric pits
The entire surface of the stomach is covered in tiny holes, which lead to the glands that produce mucus, acid and enzymes.

Chief cell (yellow)
Chief cells make pepsinogen; at the low pH in the stomach it becomes the digestive enzyme pepsin, which deconstructs protein.

Mucous cell
These cells secrete alkaline mucus to protect the stomach lining from damage by stomach acid.

G-cell (pink)
Also known as enteroendocrine cells, these produce hormones like gastrin, which regulate acid production and stomach contraction.

Parietal cell (blue)
These cells produce hydrochloric acid, which kills off micro-organisms, unravels proteins and activates digestive enzymes.

Muscle layers
The stomach has three layers of muscle running in different orientations. These produce the co-ordinated contraction required to mix food.

THE STATS
GASTRIC FIGURES

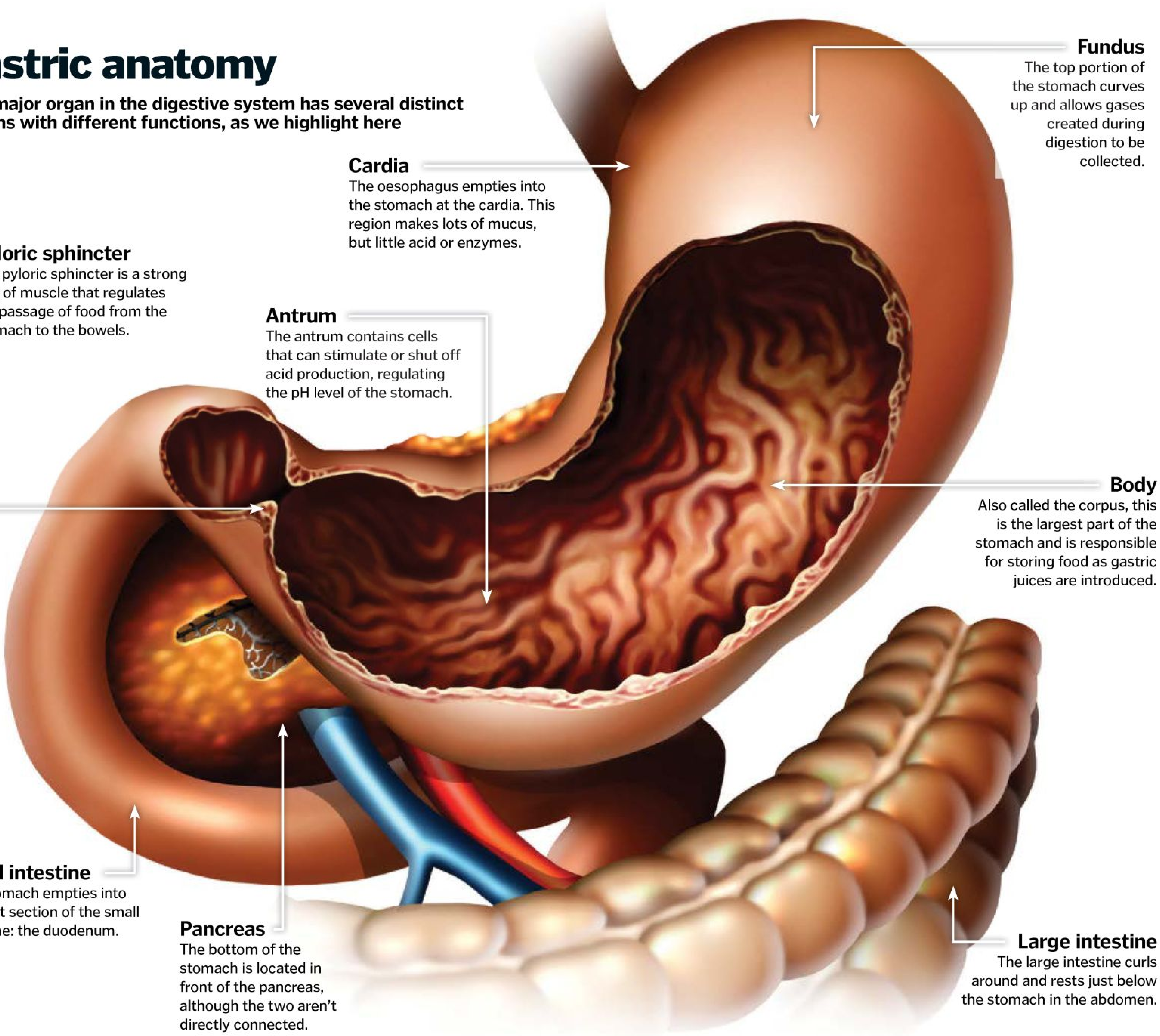
VOLUME WHEN EMPTY **50ml** | GASTRIC ACID PRODUCED **2 litres/day** | AVERAGE pH LEVEL **2.5**

CAPACITY **1-4 litres** | EMPTYING TIME **4-5hrs** | LENGTH **25cm**

DID YOU KNOW? *Stomach rumbling, also known as borborygmus, is actually the noise of air movement in the intestines*

Gastric anatomy

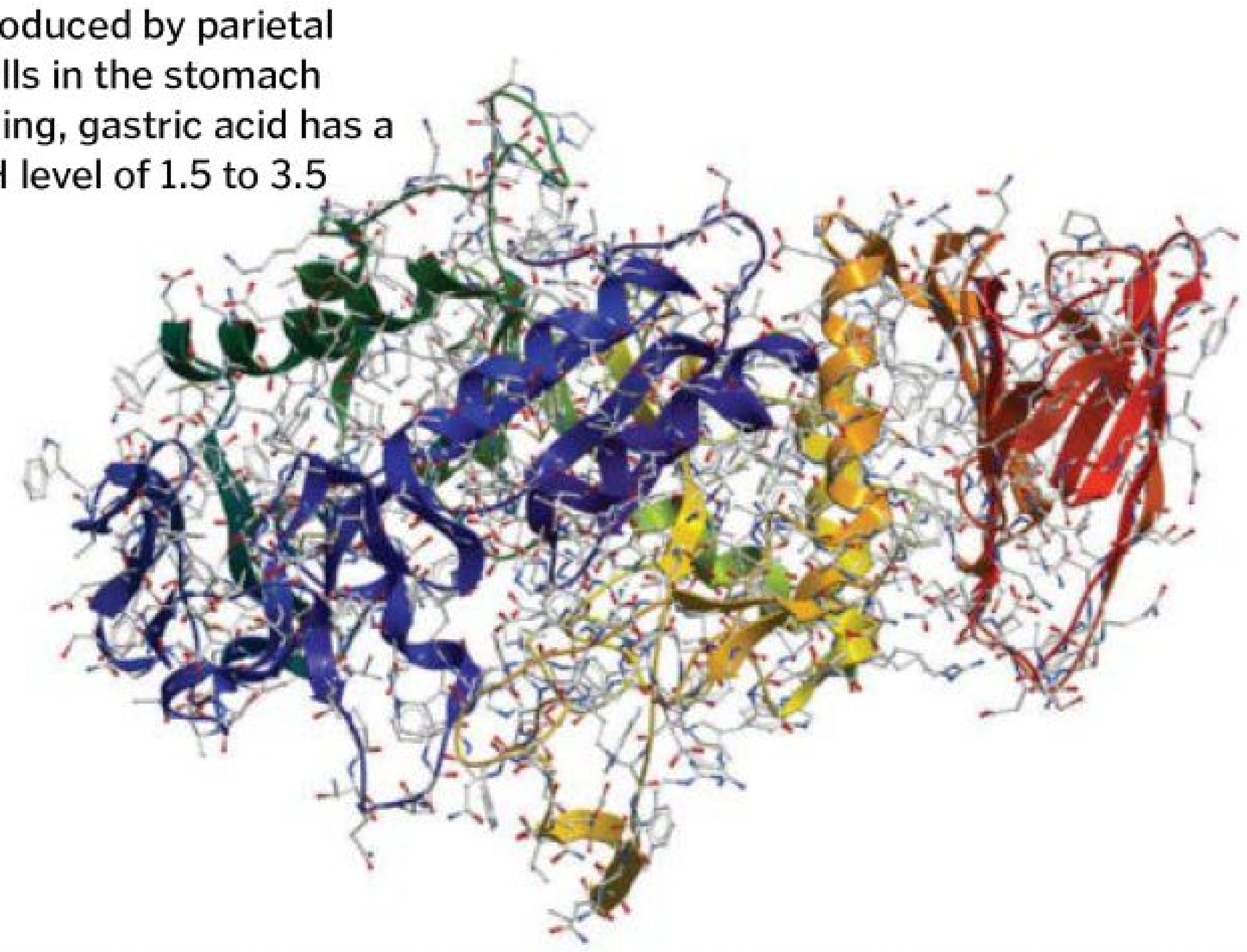
This major organ in the digestive system has several distinct regions with different functions, as we highlight here



Why doesn't it digest itself?

Your stomach is full of corrosive acid and enzymes capable of breaking down protein – if left unprotected the stomach lining would quickly be destroyed. To prevent this from occurring, the cells lining the stomach wall produce carbohydrate-rich mucus, which forms a slippery, gel-like barrier. The mucus contains bicarbonate, which is alkaline and buffers the pH at the surface of the stomach lining, preventing damage by acid. For added protection, the protein-digesting enzyme pepsin is created from a zymogen (the enzyme in its inactive form) – pepsinogen; it only becomes active when it comes into contact with acid, a safe distance away from the cells that manufacture it.

Produced by parietal cells in the stomach lining, gastric acid has a pH level of 1.5 to 3.5



Vomit reflex step-by-step

Vomiting is the forceful expulsion of the stomach contents up the oesophagus and out of the mouth. It's the result of three co-ordinated stages. First, a deep breath is drawn and the body closes the glottis, covering the entrance to the lungs. The diaphragm then contracts, lowering pressure in the thorax to open up the oesophagus. At the same time, the muscles of the abdominal wall contract, which squeezes the stomach. The combined shifts in pressure both inside and outside the stomach forces any contents upwards.

"Peristalsis is the movement used by the small intestine to push the food through to the large bowel"

The surface area of the small intestine is huge – in fact, rolled flat it would cover a tennis court!

Exploring the small intestine

Crucial for getting the nutrients we need from the food we eat, how does this digestive organ work?

The small intestine is one of the most important elements of our digestive system, which enables us to process food and absorb nutrients. On average, it sits at a little over six metres (19.7 feet) long with a diameter of 2.5-3 centimetres (1-1.2 inches), and it's made up of three distinctive parts: the duodenum, jejunum and the ileum.

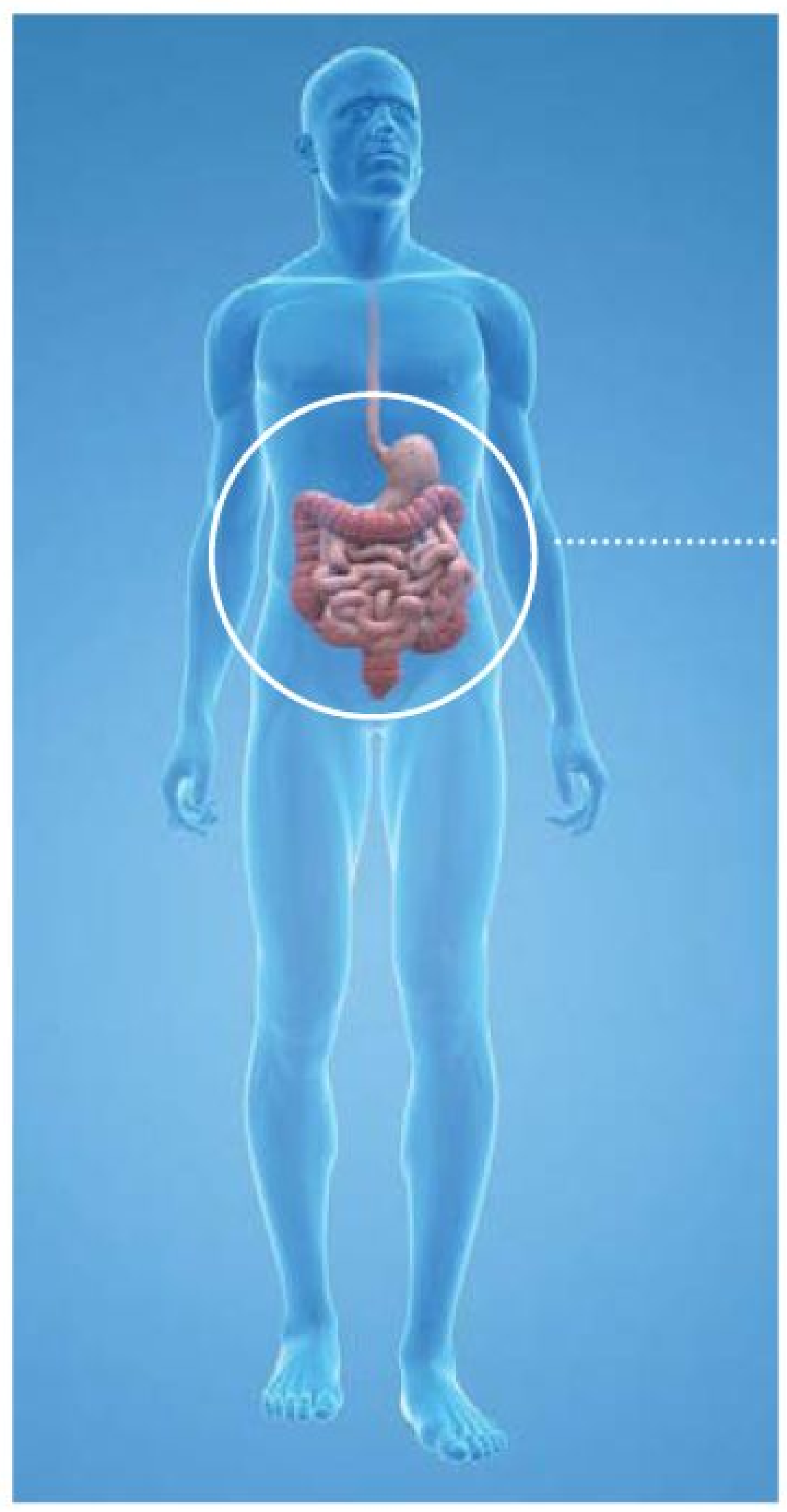
The duodenum connects the small intestine to the stomach and is the key place for further enzyme breakdown, following the stomach turning food into an amino acid state. While the duodenum is very important in breaking food down, using bile and enzymes from the gallbladder, liver and pancreas, it is the shortest element of the small bowel, only averaging about 30 centimetres (11.8 inches).

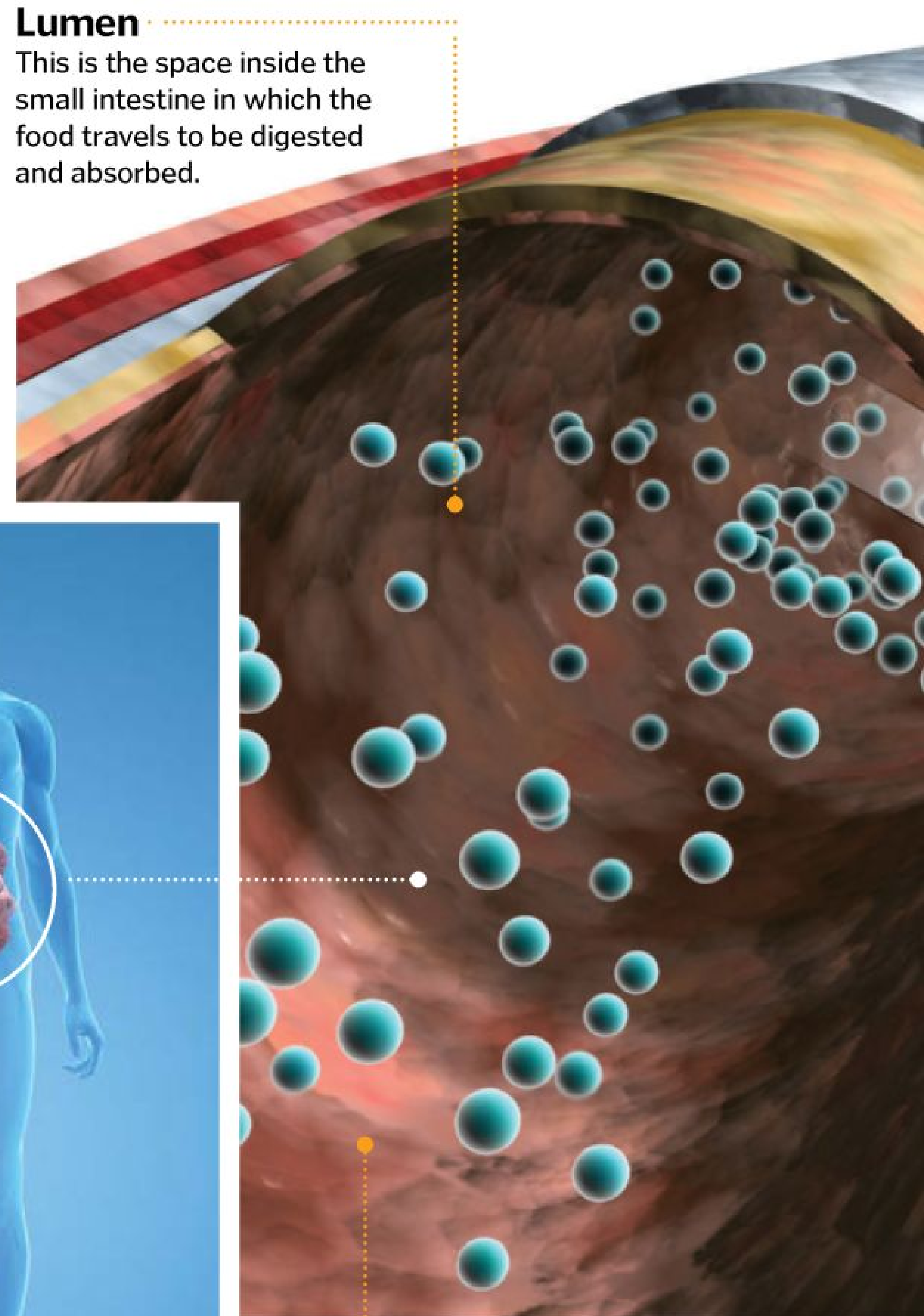
The jejunum follows the duodenum and its primary function is to encourage absorption of carbohydrates and proteins by passing the broken-down food molecules through an area with a large surface area so they can enter the bloodstream. Villi – small finger-like structures – and mucosal folds line the passage and increase the surface area dramatically to aid this process. The ileum is the final section of the small bowel and serves to catch nutrients that may have been missed, as well as absorbing vitamin B12 and bile salts.

Peristalsis is the movement used by the small intestine to push the food through to the large bowel, where waste matter is stored for a short period then ultimately disposed of via the colon. This process of contraction and relaxation is generated by a series of muscles which make up the organ's outer wall.

Structure of the small intestine

Examine the anatomy of this vital organ in the human digestive tract





Lumen
This is the space inside the small intestine in which the food travels to be digested and absorbed.

Mucosa
The internal lining of the small intestine where the plicae circulares (mucosal folds) and villi are situated.

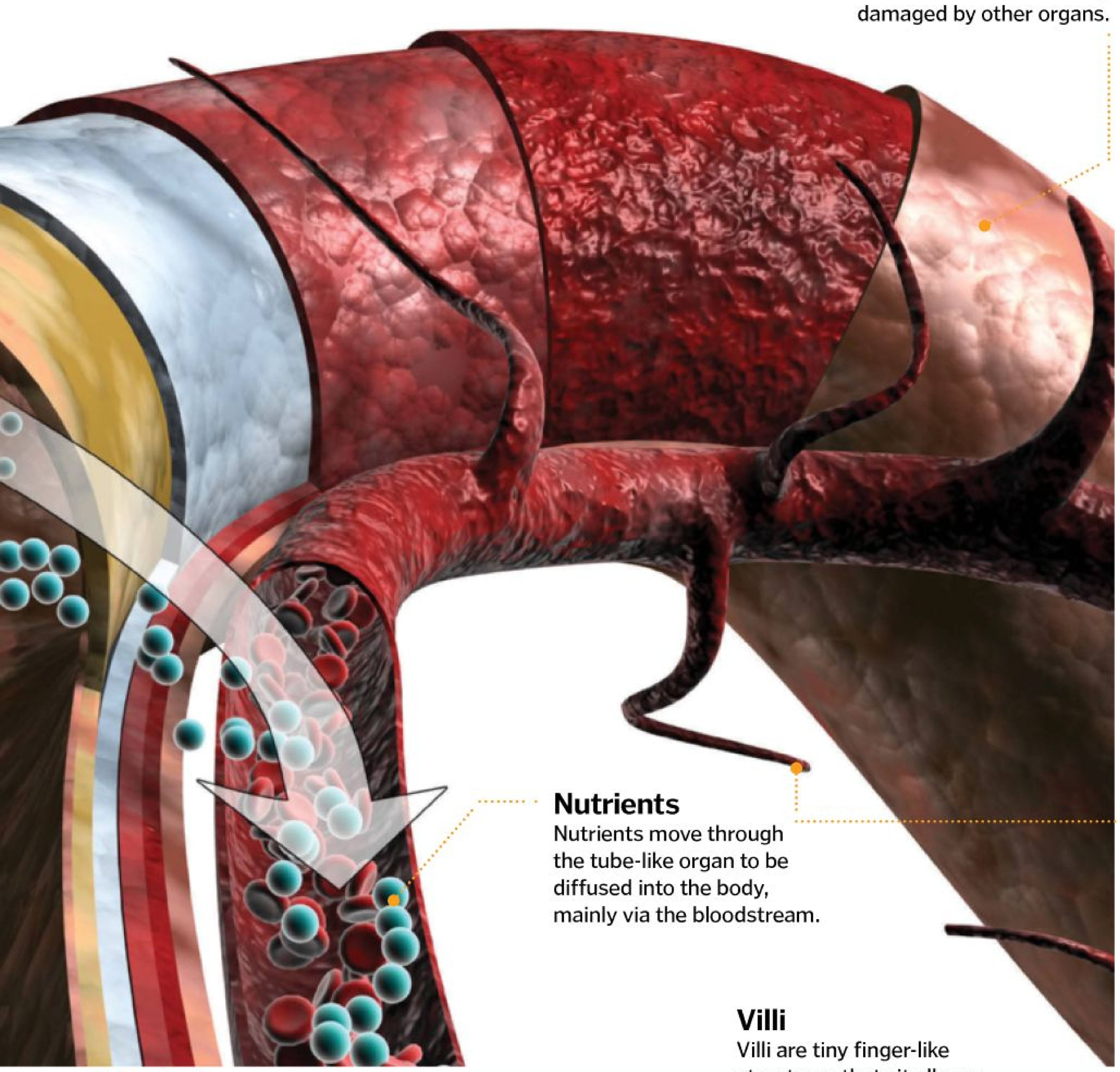
Mucosal folds
These line the small intestine to increase surface area and help push the food on its way by creating a valve-like structure, stopping food travelling backwards.

Submucosa
This supports the mucosa and connects it to the layers of muscle (muscularis) that make up the exterior of the small intestine.

THE STATS SMALL BOWEL

LENGTH	6m
DIAMETER	2.5-3cm
TIME IT TAKES FOOD TO PASS THROUGH	1-4 hours
SURFACE AREA	$250m^2$
AMOUNT OF BODY'S NUTRIENT ABSORPTION	90%
NUMBER OF VILLI PER SQUARE MM	10-40

DID YOU KNOW? *The small intestine is actually longer than the large intestine, but is so called because of its narrower diameter*



Serosa
This protective outer layer stops the small intestine from being damaged by other organs.

Nutrients
Nutrients move through the tube-like organ to be diffused into the body, mainly via the bloodstream.

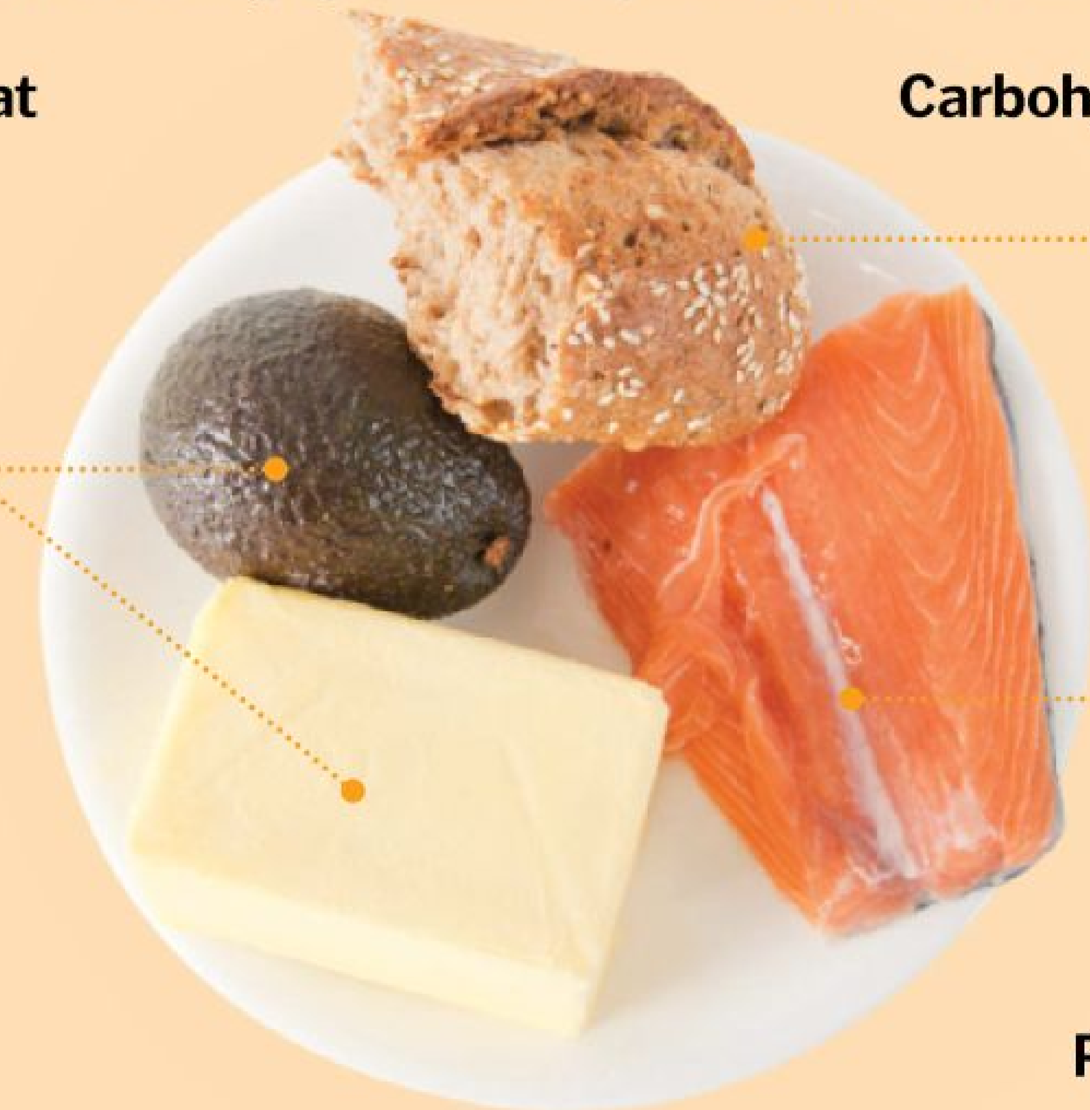
Blood vessels
These sit close to the small intestine to allow easy diffusion of nutrients into the bloodstream.

Longitudinal muscle layer
This contracts and extends to help transport food with the circular muscle layer.

Circular muscle layer
This works in partnership with the longitudinal muscle layer to push the food down via a process called peristalsis.

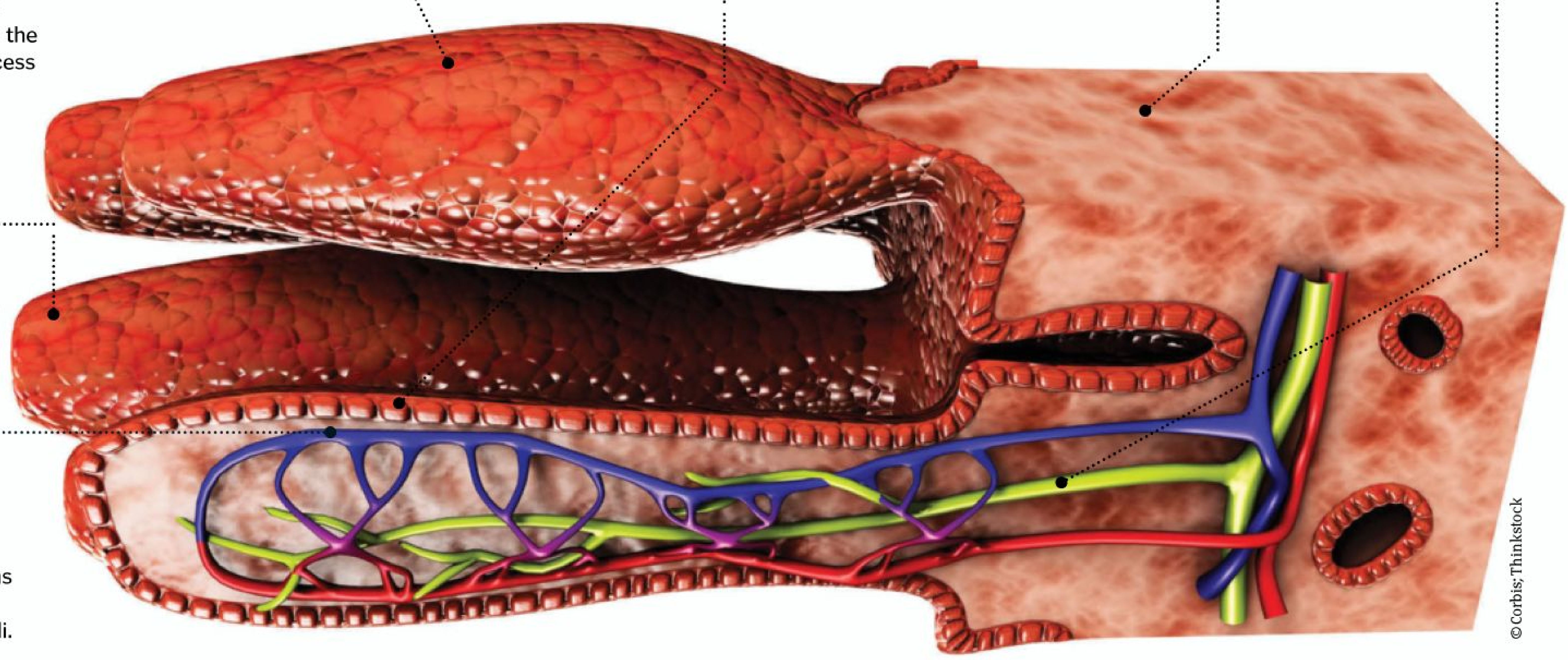
What exactly are nutrients?

There are three main types of nutrient that we process in the body: lipids (fats), carbohydrates and proteins. These three groups of molecules are broken down into sugars, starches, fats and smaller, simpler molecule elements, which we can absorb through the small intestine walls and that then travel in the bloodstream to our muscles and other areas of the body that require energy or to be repaired. We also need to consume and absorb vitamins and minerals that we can't synthesise within the body, eg vitamin B12 (prevalent in meat and fish).



A closer look at villi

What role do these little finger-like protrusions play in the bowel?



Villi
Villi are tiny finger-like structures that sit all over the mucosa. They help increase the surface area massively, alongside the mucosal folds.

Epithelium (epithelial cells)
These individual cells that sit in the mucosa layer are where individual microvilli extend from.

Mucosa
The lining of the small intestine on which villi are located.

Lacteal
The lacteal is a lymphatic capillary that absorbs nutrients that can't pass directly into the bloodstream.

Microvilli
These are a mini version of villi and sit on villi's individual epithelial cells.

Capillary bed
These absorb simple sugars and amino acids as they pass through the epithelial tissue of the villi.

"Air is drawn into the lungs at a rate of between 10-20 breaths per minute while resting"

Human respiration

Respiration is crucial to an organism's survival. The process of respiration is the transportation of oxygen from the air that surrounds us into the tissue cells of our body so that energy can be broken down

The primary organs used for respiration in humans are the lungs. Humans have two lungs, with the left lung being divided into two lobes and the right into three. The lungs have between 300–500 million alveoli, which is where gas exchange occurs.

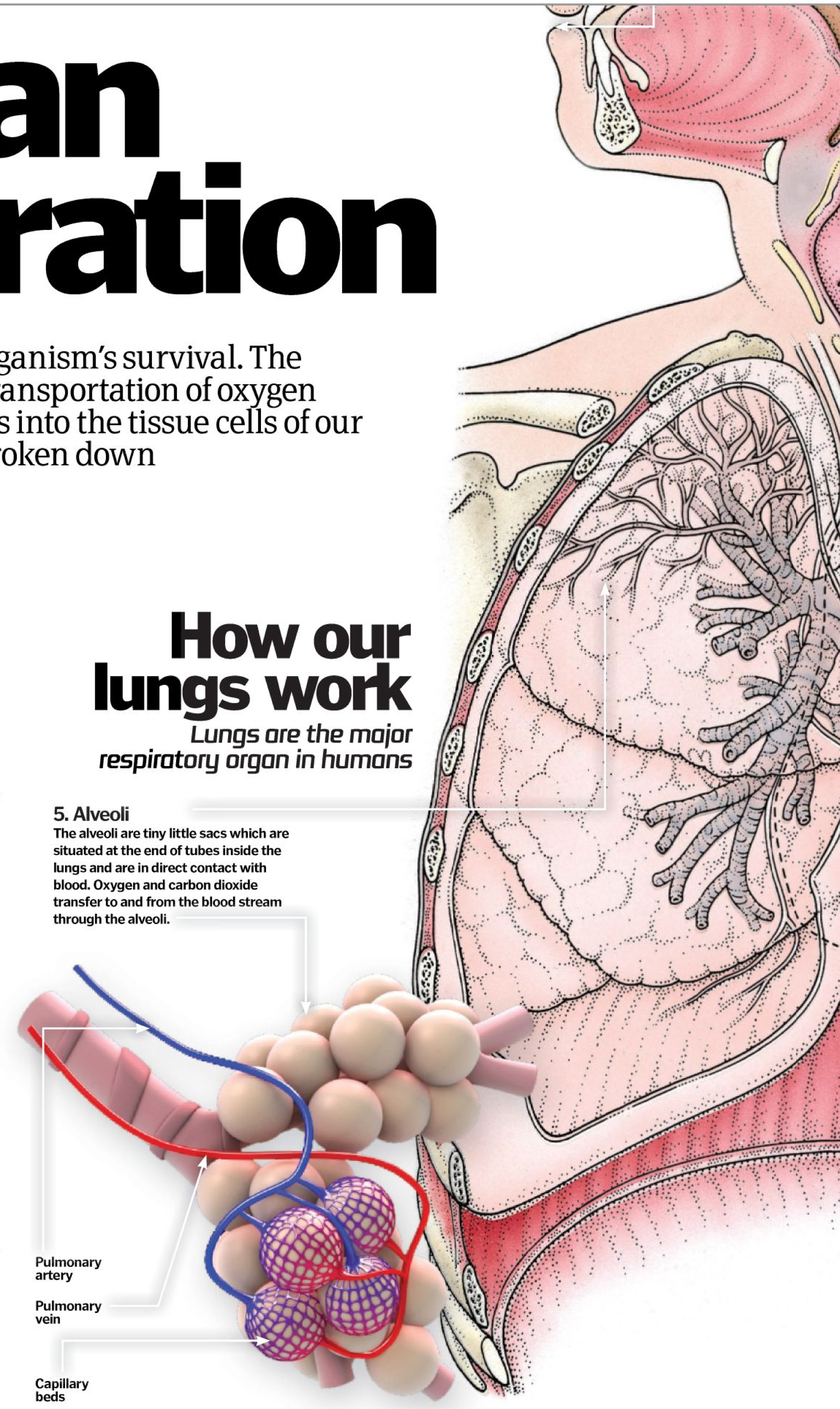
Respiration of oxygen breaks into four main stages: ventilation, pulmonary gas exchange, gas transportation and peripheral gas exchange. Each stage is crucial in getting oxygen to the body's tissue, and removing carbon dioxide. Ventilation and gas transportation need energy to occur, as the diaphragm and the heart are used to facilitate these actions whereas gas exchanging is passive. As air is drawn into the lungs at a rate of between 10-20 breaths per minute while resting, through either your mouth or nose by diaphragm contraction, and travels through the pharynx, then the larynx, down the trachea, and into one of the two main bronchial tubes. Mucus and cilia keep the lungs clean by catching dirt particles and sweeping them up the trachea.

When air reaches the lungs, oxygen is diffused into the bloodstream through the alveoli and carbon dioxide is diffused from the blood into the lungs to be exhaled. Diffusion of gases occurs because of differing pressures in the lungs and blood. This is also the same when oxygen diffuses into tissue around the body. When blood has been oxygenated by the lungs, it is transferred around the body to where it is most needed in the bloodstream. If the body is exercising, breathing rate increases and consequently so does heart rate to ensure that oxygen reaches tissues that need it. Oxygen is then used to break down glucose to provide energy for the body. This happens in the mitochondria of cells. Carbon dioxide is one of the waste products of this, which is why we get a build up of this gas in our body that needs to be transported back into the lungs to be exhaled.

The body can also respire anaerobically, but this produces far less energy and instead of producing CO_2 as a byproduct, lactic acid is produced. The body then takes a time to break this down after exertion has finished as the body has a so-called oxygen debt.

How our lungs work

Lungs are the major respiratory organ in humans



5 TOP FACTS
RESPIRATION

Lung capacity varies hugely
1 Dependant on sex and body size, alongside external factors such as altitude, lung capacity ranges between 4,000 and 6,000cm³.

The right lung is bigger
2 The left lung is slightly smaller than the right because the left lung has to make room for the heart to fit in.

We have excess lung capacity
3 On average, we only use about one-eighth of the capacity of our lungs for each breath so we have a large reserve volume.

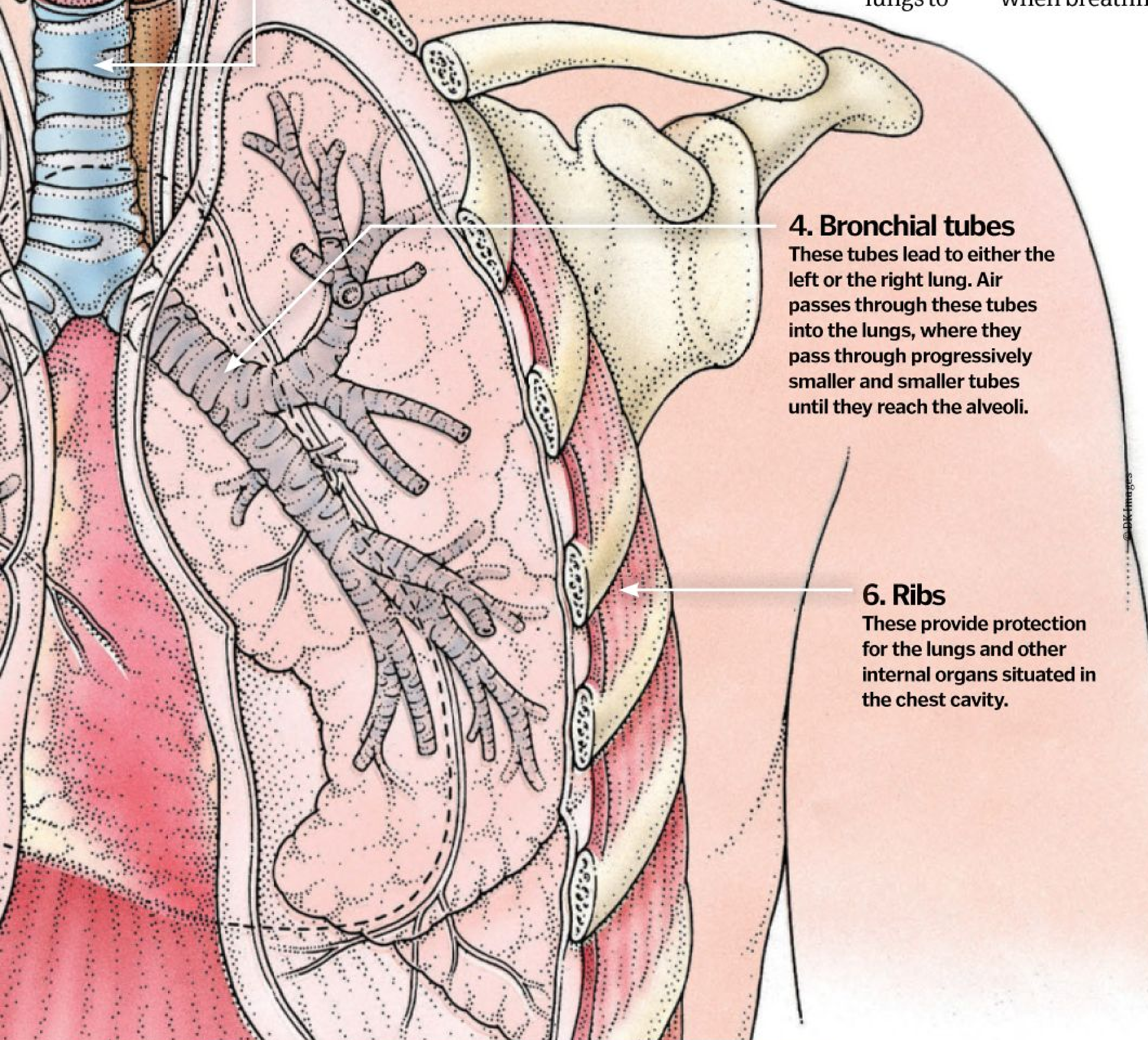
Alveoli have massive surface area
4 One person's entire alveoli laid out would have the surface area of about 70cm² – roughly half a tennis court!

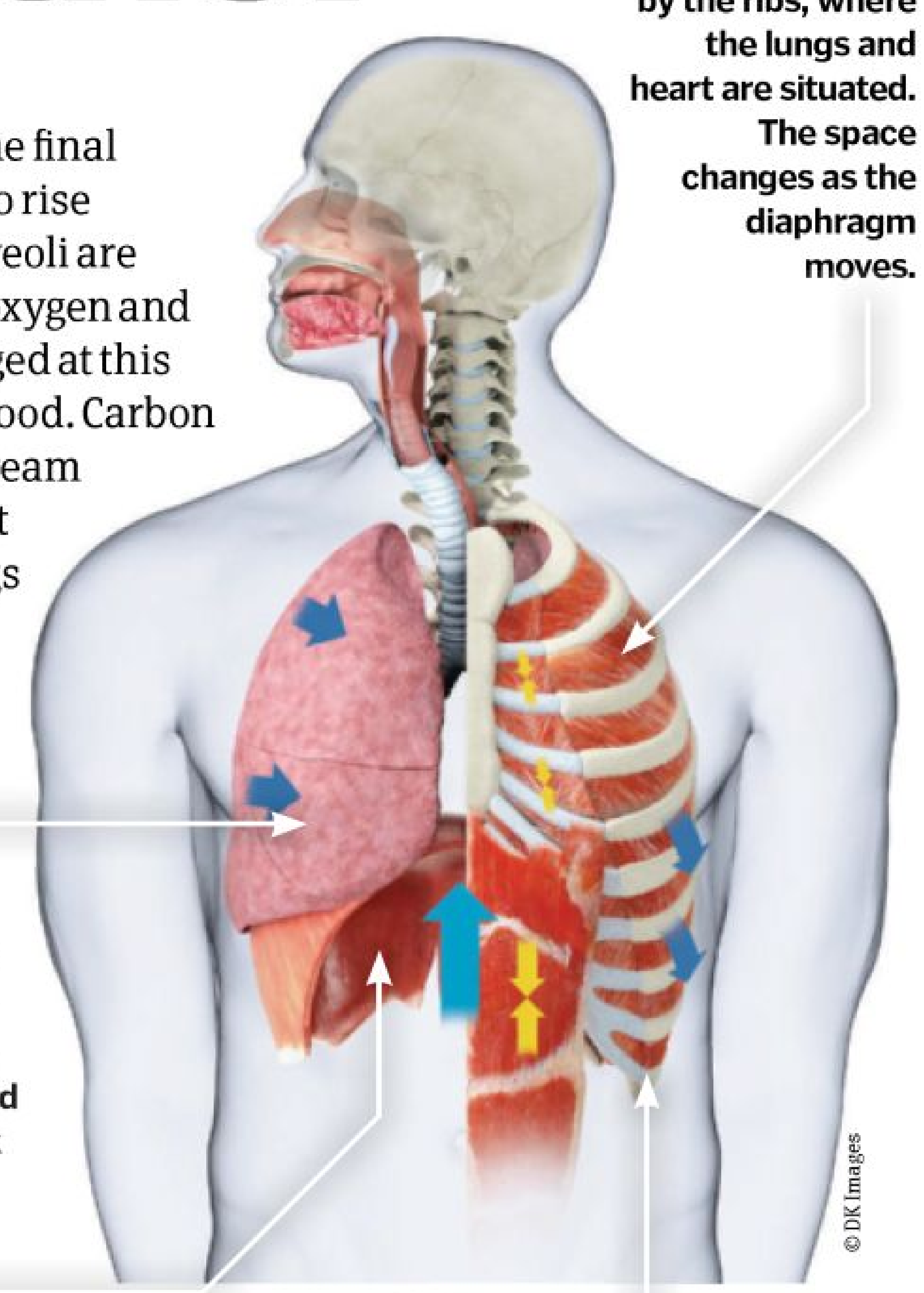
We breathe 11,000 litres of air per day
5 On average, one individual will breathe in 11,000 litres of air a day. If we exercise heavily during that day, this will increase further.

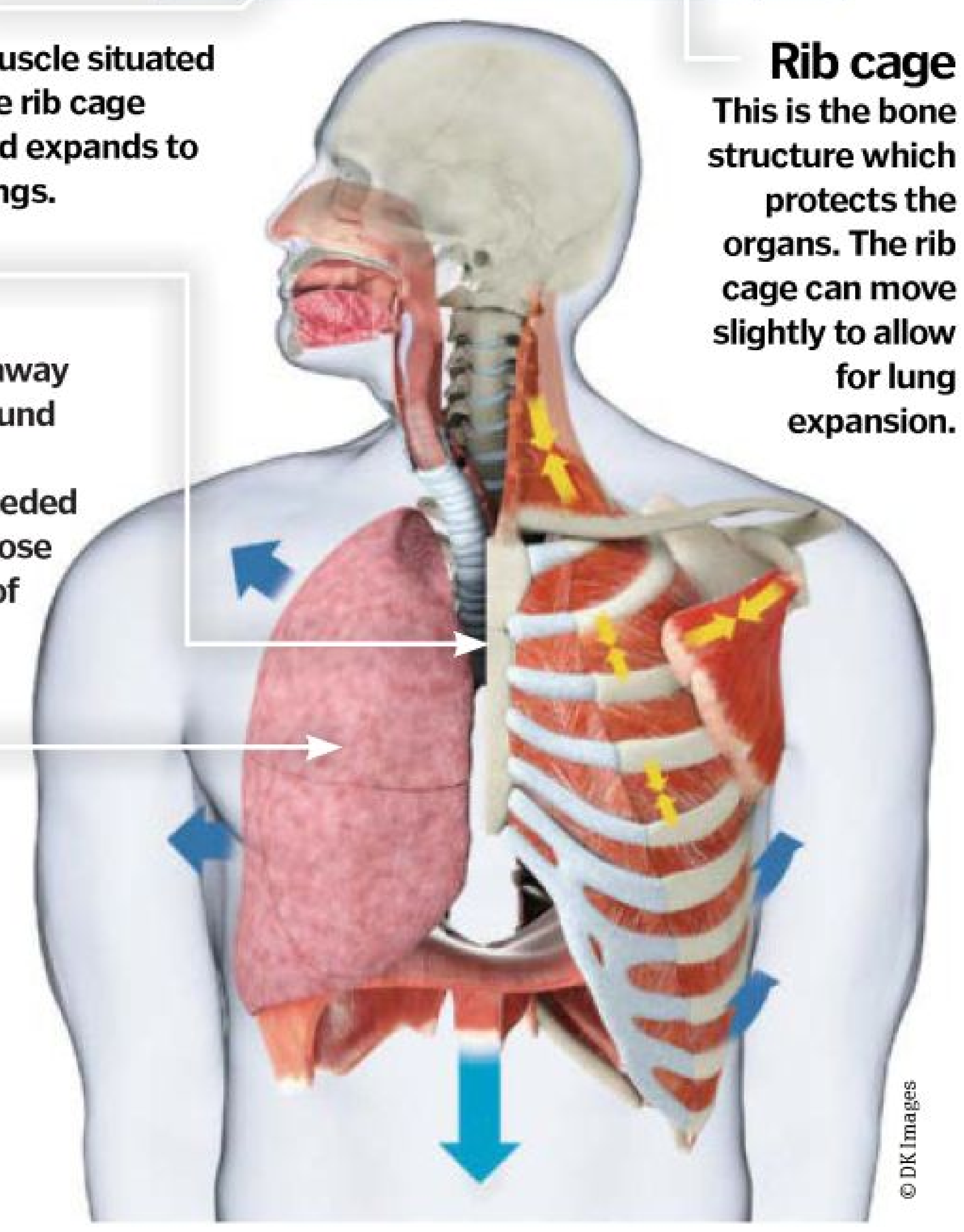
DID YOU KNOW? *Trained free-divers can hold their breath underwater for up to nine minutes*

How do we breathe?
The intake of oxygen into the body is complex

Breathing is not something that we have to think about, and indeed is controlled by muscle contractions in our body. Breathing is controlled by the diaphragm, which contracts and expands on a regular, constant basis. When it contracts, the diaphragm pulls air into the lungs by a vacuum-like effect. The lungs expand to fill the enlarged chest cavity and air is pulled right through the maze of tubes that make up the lungs to the alveoli at the ends, which are the final branching. The chest will be seen to rise because of this lung expansion. Alveoli are surrounded by blood vessels, and oxygen and carbon dioxide are then interchanged at this point between the lungs and the blood. Carbon dioxide removed from the blood stream and air that was breathed in but not used is then expelled from the lungs by diaphragm expansion. Lungs deflate back to a reduced size when breathing out.







Why do we need oxygen?
We need oxygen to live as it is crucial for the release of energy within the body

Although we can release energy through anaerobic respiration temporarily, this method is inefficient and creates an oxygen debt that the body must repay after excess exercise or exertion has ceased. If oxygen supply is cut off for more than a few minutes, an individual will die.

Oxygen is pumped around the body to be used in cells that need to break down glucose so that energy is provided for the tissue. The equation that illustrates this is:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{energy}$$

> "The connections inside a brain are very similar to the internet – they are constantly exchanging information"

EXPLAINED…

Your brain

The human brain is the most mysterious – and complex – entity in the known universe

It's a computer, a thinking machine, a fatty pink organ, and a vast collection of neurons – but how does it actually work? The human brain is amazingly complex – in fact, more complex than anything in the known universe. The brain effortlessly consumes power, stores memories, processes thoughts, and reacts to danger.

In some ways, the human brain is like a car engine. The fuel – which could be the sandwich you had for lunch or a sugar doughnut for breakfast – causes neurons to fire in a logical sequence and to bond with other neurons. This combination of neurons occurs incredibly fast, but the chain reaction might help you compose a symphony or recall entire passages of a book, help you pedal a bike or write an email to a friend.

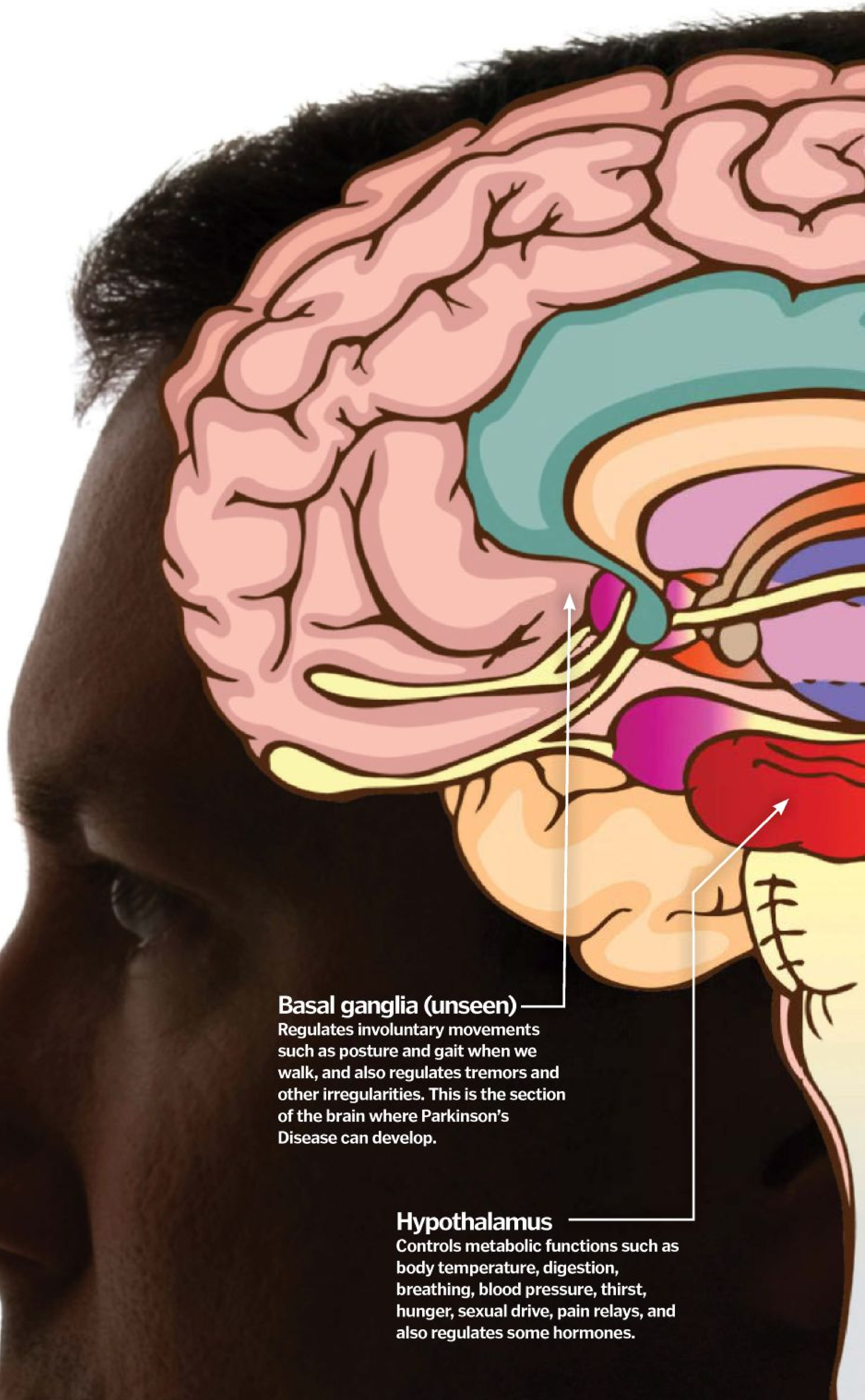
Scientists are just beginning to understand how these brain neurons work – they have not figured out how they trigger a reaction when you touch a hot stove, for example, or why you can re-generate brain cells when you work out at the gym.

The connections inside a brain are very similar to the internet – the connections are constantly exchanging information. Yet, even the internet is rather simplistic when compared to neurons.

There are ten to 100 neurons, and each one makes thousands of connections. This is how the brain processes information, or determines how to move an arm and grip a surface. These calculations, perceptions, memories, and reactions occur almost instantaneously, and not just a few times per minute, but millions. According to Jim Olds, research director with George Mason University, if the internet were as complex as our solar system, then the brain would be as complex as our galaxy. In other words, we have a lot to learn. Science has not given up trying, and has made recent discoveries about how we adapt, learn new information, and can actually increase brain capability.

In the most basic sense, our brain is the centre of all input and outputs in the human body. Dr Paula Tallal, a co-director of neuroscience at Rutgers University, says the brain is constantly processing sensory information – even from infancy. "It's easiest to think of the brain in terms of inputs and outputs," says Tallal. "Inputs are sensory information, outputs are how our brain organises that information and controls our motor systems."

Tallal says one of the primary functions of the brain is in learning to predict what comes next. In her research for Scientific Learning, she has found that young children enjoy having the same book read to them again and again because that is how the brain registers acoustic cues that form into phonemes



Parts of the brain

So what are the parts of the brain? According to Olds, there are almost too many to count – perhaps a hundred or more, depending on who you ask. However, there are some key areas that control certain functions and store thoughts and memories.

LARGEST

Sperm whale
The sperm whale has evolved the largest brain ever to exist on our planet, weighing as much as nine kilograms or 20 pounds.

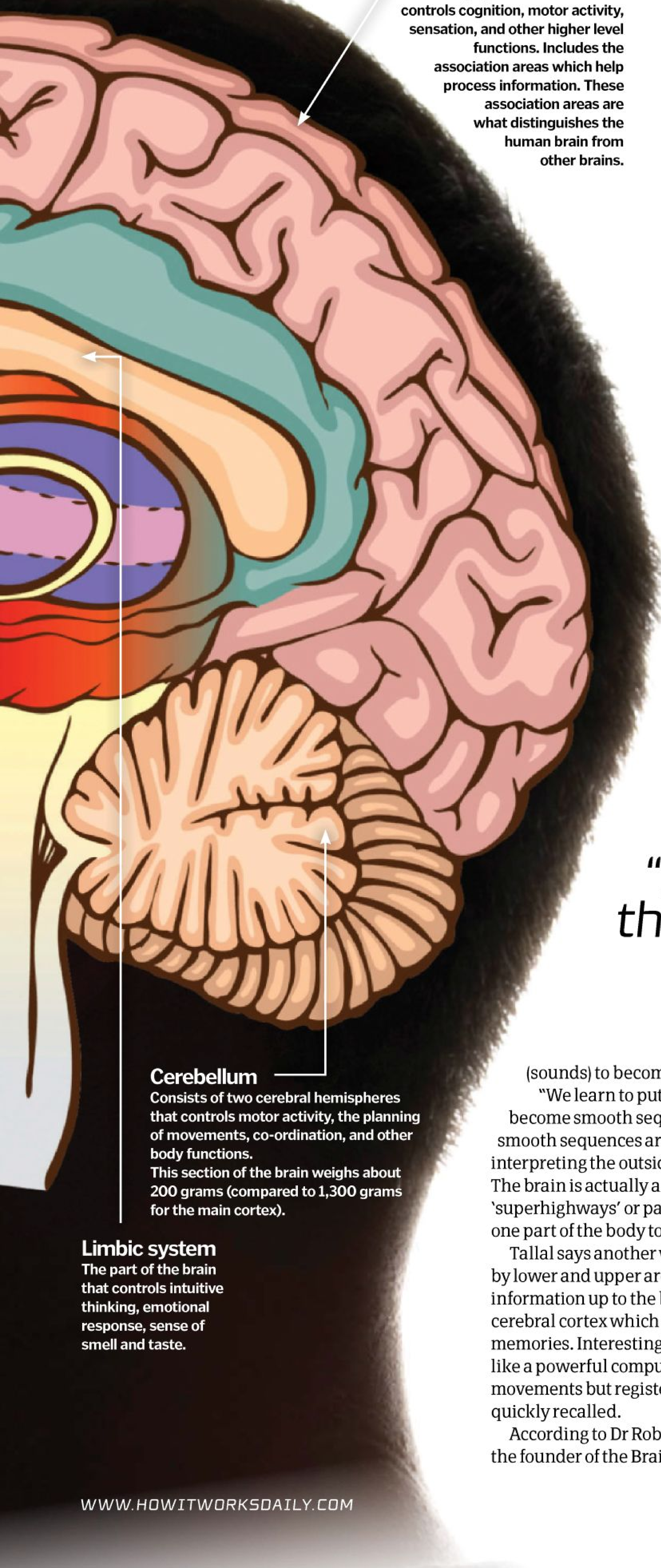
SMALLEST

Mouse lemur
The smallest primate brain is owned by the pygmy mouse lemur of Madagascar and weighs in at just 0.004 pounds (2g).

LARGEST ON LAND

Elephant
At 10.5 pounds (4.78kg) it's certainly a big one. But still, the brain of the elephant makes up less than 0.1 per cent of its body weight.

DID YOU KNOW? The average human brain is 140mm wide x 167mm long x 93mm high



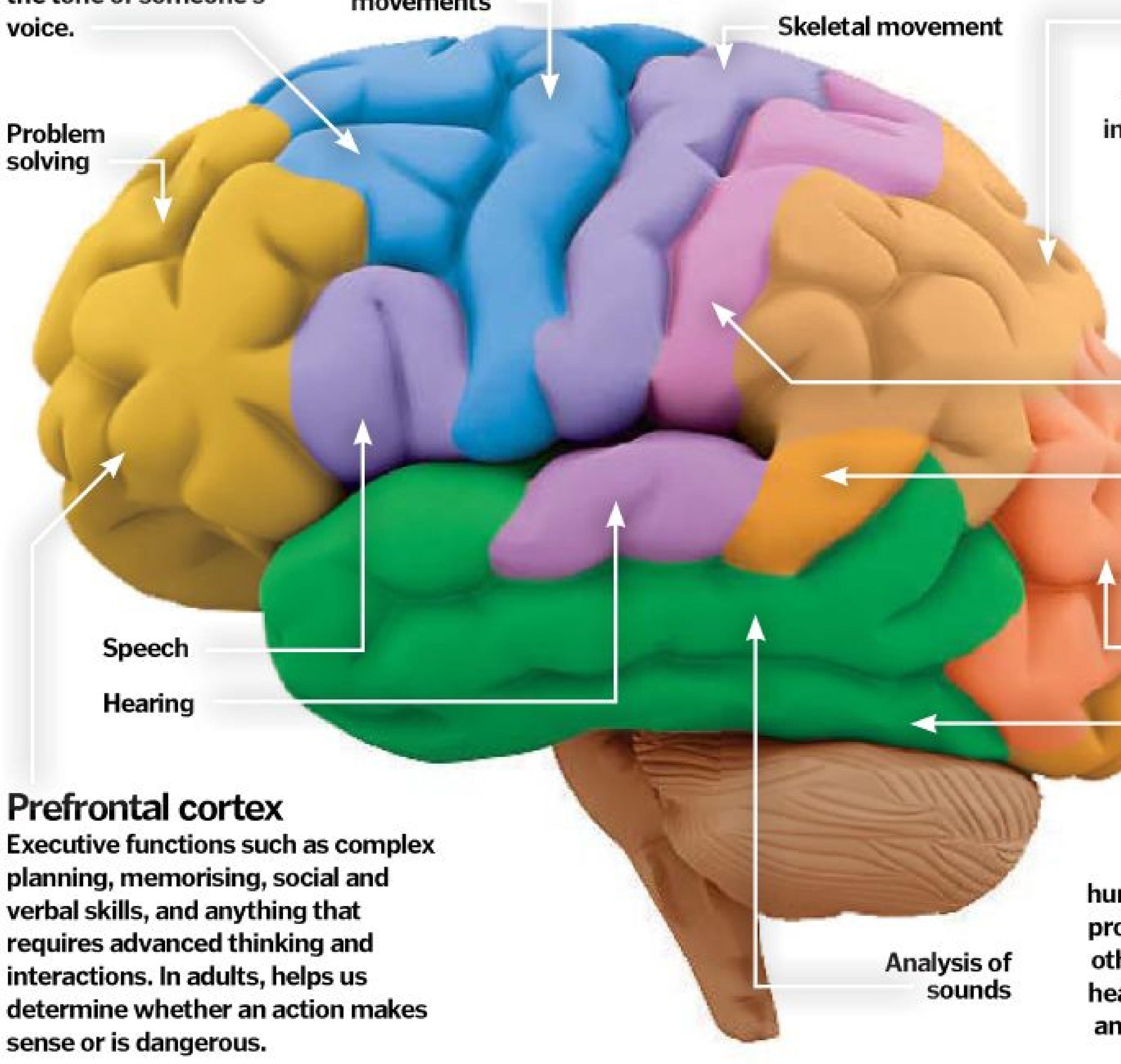
Cerebral cortex
The 'grey matter' of the brain controls cognition, motor activity, sensation, and other higher level functions. Includes the association areas which help process information. These association areas are what distinguishes the human brain from other brains.

Cerebellum
Consists of two cerebral hemispheres that controls motor activity, the planning of movements, co-ordination, and other body functions.
This section of the brain weighs about 200 grams (compared to 1,300 grams for the main cortex).

Limbic system
The part of the brain that controls intuitive thinking, emotional response, sense of smell and taste.

Functions of the cerebral cortex

The cerebral cortex is the wrinkling part of our brain that shows up when you see pictures of the brain



Frontal lobe
Primarily controls senses such as taste, hearing, and smell. Association areas might help us determine language and the tone of someone's voice.

Parietal lobe
Where the brain senses touch and anything that interacts with the surface of the skin, makes us aware of the feelings of our body and where we are in space.

Prefrontal cortex
Executive functions such as complex planning, memorising, social and verbal skills, and anything that requires advanced thinking and interactions. In adults, helps us determine whether an action makes sense or is dangerous.

Temporal lobe
What distinguishes the human brain – the ability to process and interpret what other parts of the brain are hearing, sensing, or tasting and determine a response.

"In a sense, the main function of the brain is in ordering information – interpreting the outside world and making sense of it"

(sounds) to become spoken words.

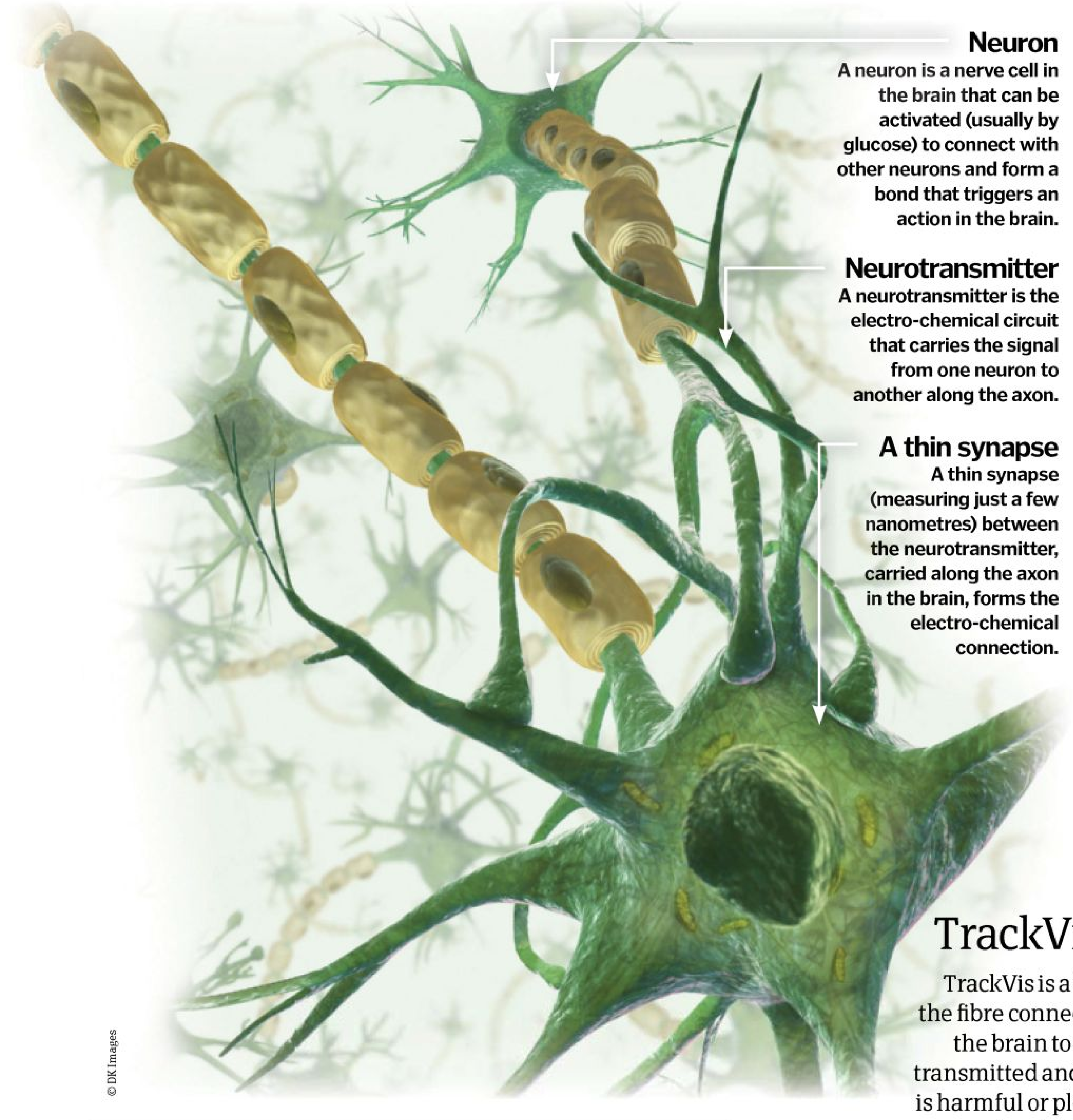
"We learn to put things together so that they become smooth sequences," she says. These smooth sequences are observable in the brain, interpreting the outside world and making sense of it. The brain is actually a series of interconnected 'superhighways' or pathways that move 'data' from one part of the body to another.

Tallal says another way to think about the brain is by lower and upper areas. The spinal cord moves information up to the brain stem, then up into the cerebral cortex which controls thoughts and memories. Interestingly, the brain really does work like a powerful computer in determining not only movements but registering memories that can be quickly recalled.

According to Dr Robert Melillo, a neurologist and the founder of the Brain Balance Centers (www.brainbalancecenters.com), says the brain actually predetermines actions and calculates the results about a half-second before performing them (or even faster in some cases). This means, when you reach out to open a door, your brain has already predetermined how to move your elbow and clasp your hand – maybe even simulated this movement more than once, before you even perform the action.

Another interesting aspect to the brain is that there are some voluntary movements and some involuntary. Some sections of the brain might control a voluntary movement – such as patting your knee to a beat. Another section controls involuntary movements, such as the gait of your walk – which is passed down from your parents. Reflexes, long-term memories, the pain reflex – they are all controlled by sections in the brain.

> "Neurones are a kind of cell in the brain that works with nearby neurones to generate an electrical charge"



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Neurons explained

Neurons fire like electrical circuits

Neurons are a kind of cell in the brain (humans have many cells in the body, including fat cells, kidney cells, and gland cells). A neuron is essentially like a hub that works with nearby neurons to generate an electrical and chemical charge. Dr Likosky of the Swedish Medical Institute says another way of thinking about neurons is that they are like a basketball and the connections (called axons) are like electrical wires that connect to other neurons. This creates a kind of circuit in the human body. Tallal explained that input from the five senses in the body cause neurons to fire.

"The more often a collection of neurons are stimulated together in time, the more likely they are to bind together and the easier and easier it becomes for that pattern of neurons to fire in synchrony as well as sequentially," says Tallal.

Brain maps

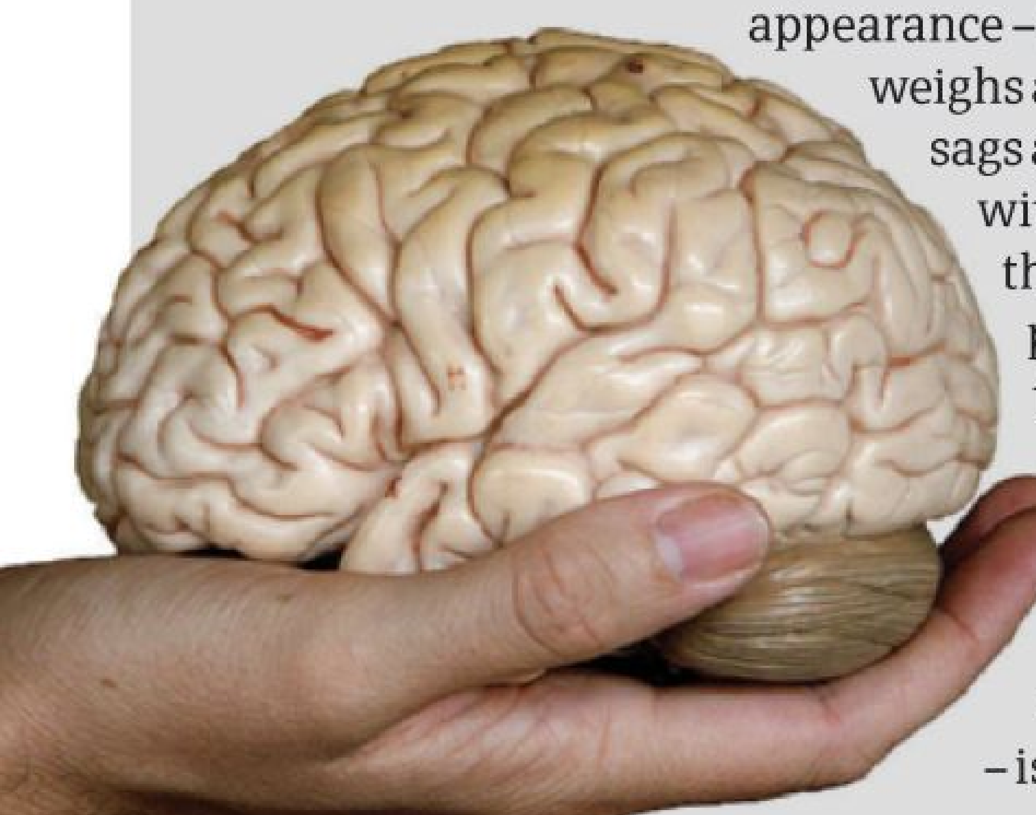
TrackVis generates unique maps of the brain

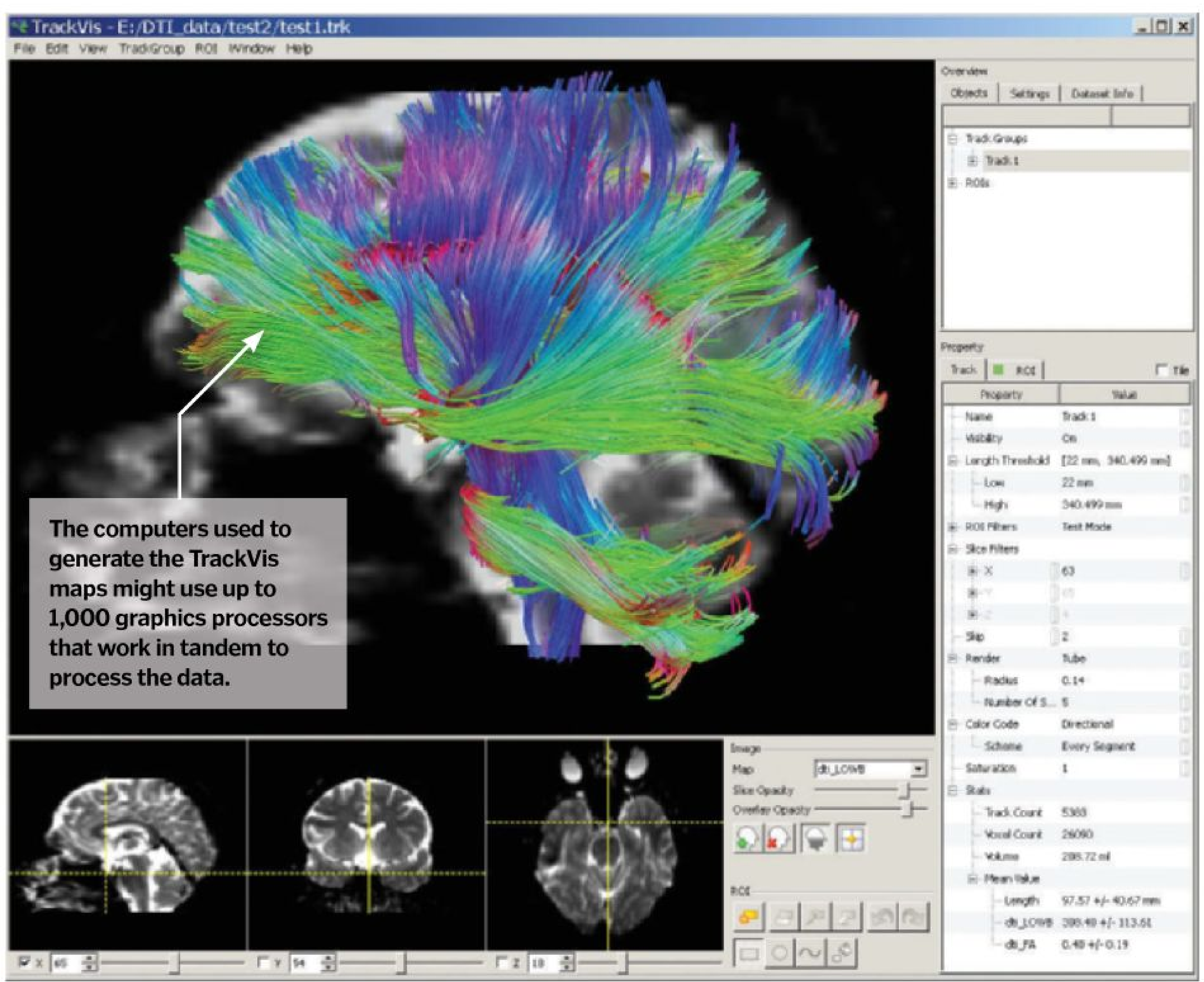
TrackVis is a free program used by neurologists to see a map of the brain that shows the fibre connections. On every brain, these neural pathways help connect one part of the brain to another so that a feeling you experience in one part of the brain can be transmitted and processed by another part of the brain (one that may decide the touch is harmful or pleasant). TrackVis uses fMRI readings on actual patients to generate the colourful and eye-catching images. To construct the maps, the program can take several hours to determine exactly how the fibres are positioning in the brain.

What is my brain like?

If you could hold it in your hand…

In pictures, the human brain often looks pink and spongy. According to Dr William Likosky, a neurologist at the Swedish Medical Institute (www.swedish.org), the brain is actually quite different from what most people think. Likosky described the brain as being not unlike feta cheese in appearance – a fragile organ that weighs about 1,500 grams and sags almost like a bag filled with water. In the skull, the brain is highly protected and has hard tissue, but most of the fatty tissue in the brain – which helps pass chemicals and other substances through membranes – is more delicate.





The computers used to generate the TrackVis maps might use up to 1,000 graphics processors that work in tandem to process the data.

5 TOP FACTS
THE BRAIN

100,000 miles of blood vessels
1 There are a staggering 100,000 miles of blood vessels in the brain, that is enough to wrap around Earth four times.

Headache not in the brain?
2 A headache actually occurs in blood vessels around the brain, not the brain itself. The brain cannot feel any pain whatsoever.

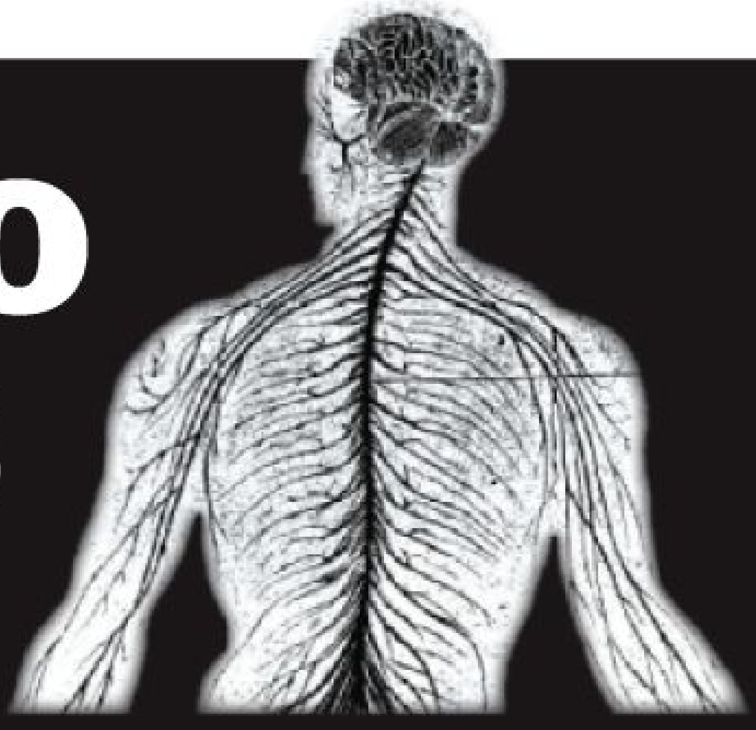
The brain is 60% fat
3 Your brain is 60 per cent fat – which helps carry water and protein through membranes to brain cells, keeping everything ticking over.

Your brain uses 20% of power
4 The brain is quite greedy; it uses about 20 per cent of the power in your body that is generated from food consumption.

Trillions of connections
5 The brain has trillions of connections – much more than the internet, and more than can currently be counted.

DID YOU KNOW? *The adult human brain weighs about 1.4kg (or three pounds)*

How do nerves work?

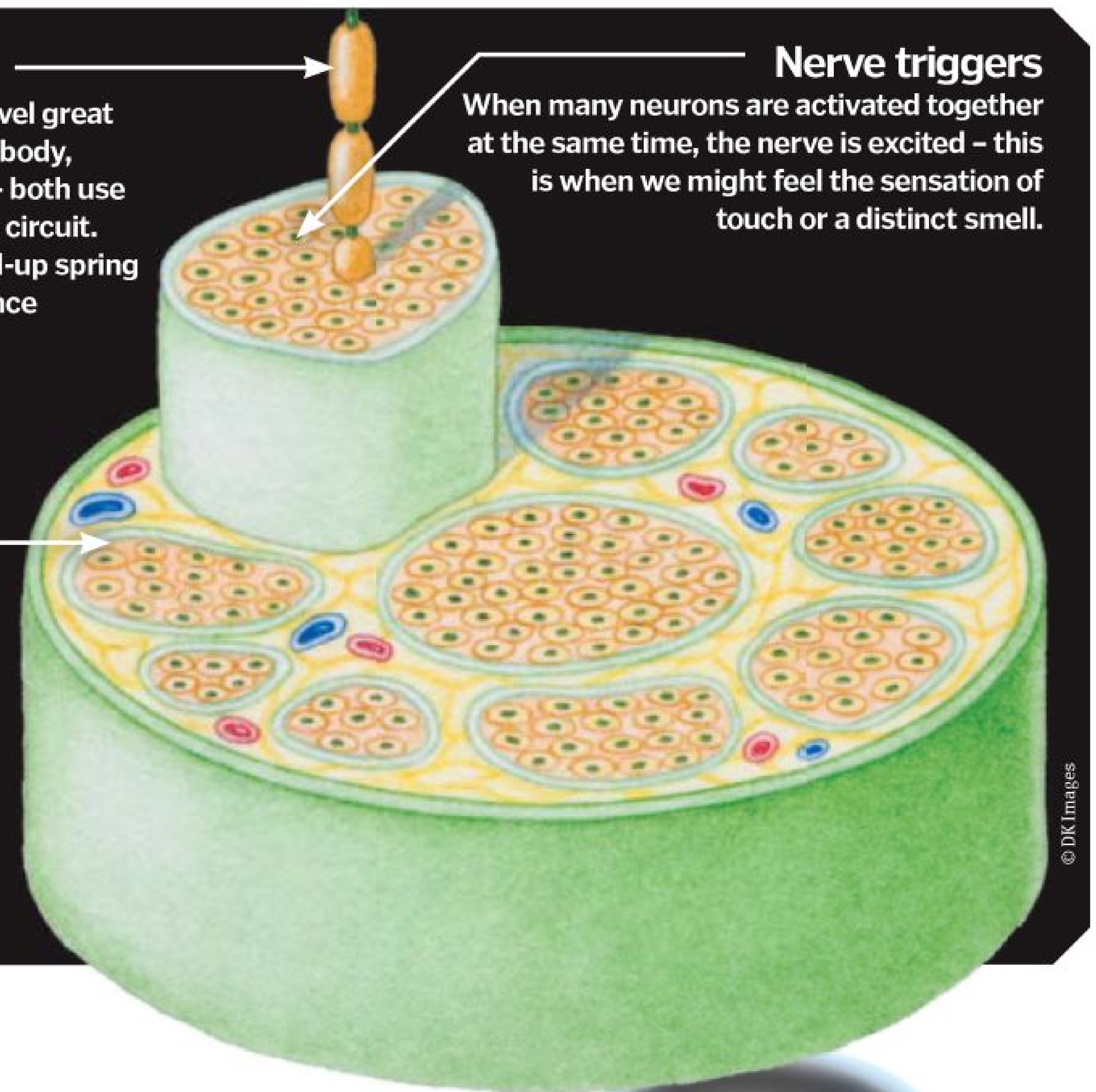


Nerves carry signals throughout the body – a chemical superhighway

Nerves are the transmission cables that carry brain waves in the human body, says Sol Diamond, an assistant professor at the Thayer School of Engineering at Dartmouth. According to Diamond, nerves communicate these signals from one point to another, whether from your toenail up to your brain or from the side of your head.

Nerve transmissions
Some nerve transmissions travel great distances through the human body, others travel short distances – both use a de-polarisation to create the circuit. De-polarisation is like a wound-up spring that releases stored energy once triggered.

Nerve triggers
When many neurons are activated together at the same time, the nerve is excited – this is when we might feel the sensation of touch or a distinct smell.



Myelinated and un-mylinated
Some nerves are myelinated (or insulated) with fatty tissue that appears white and forms a slower connection over a longer distance. Others are un-myelinated and are un-insulated. These nerves travel shorter distances.

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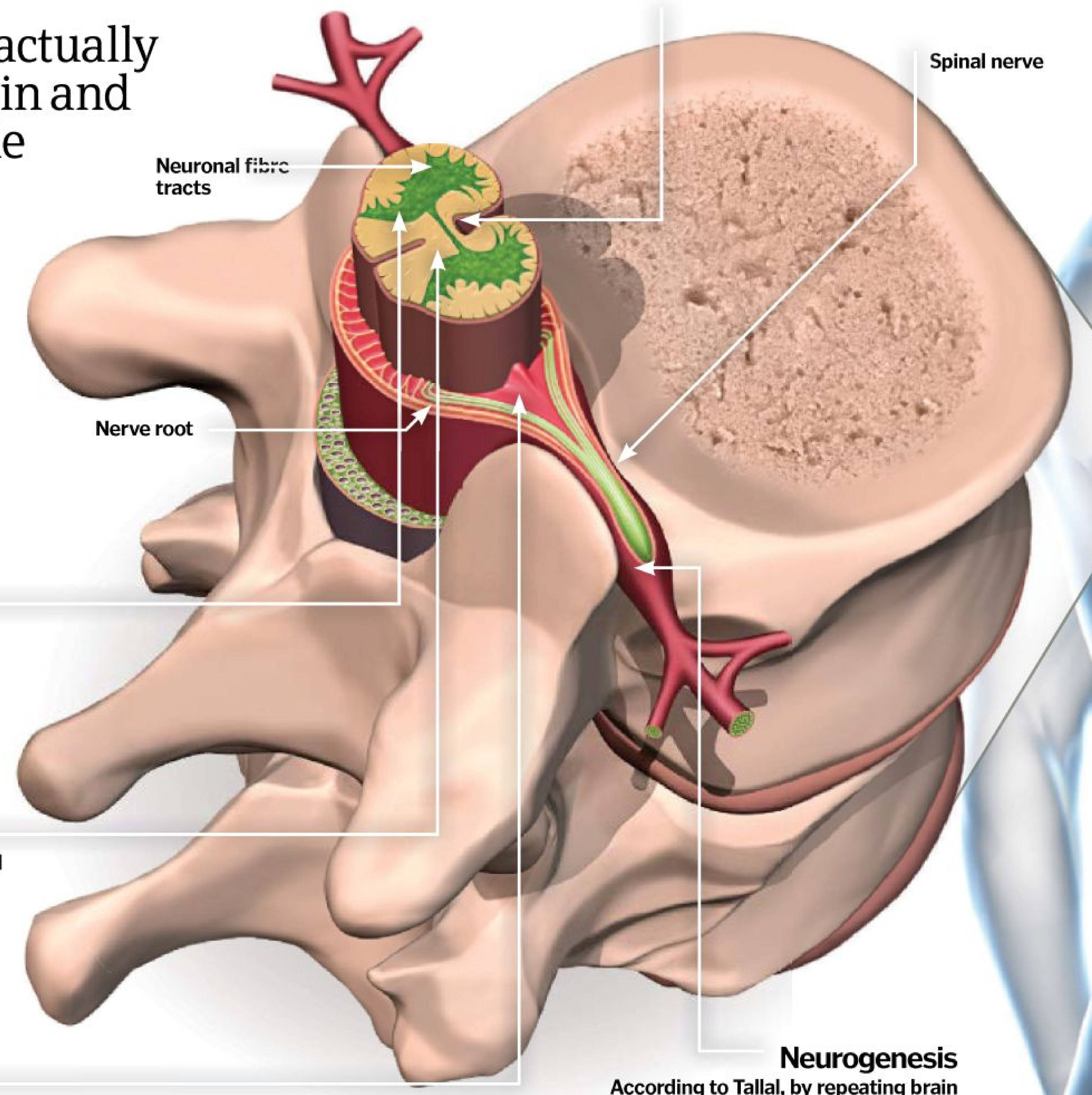
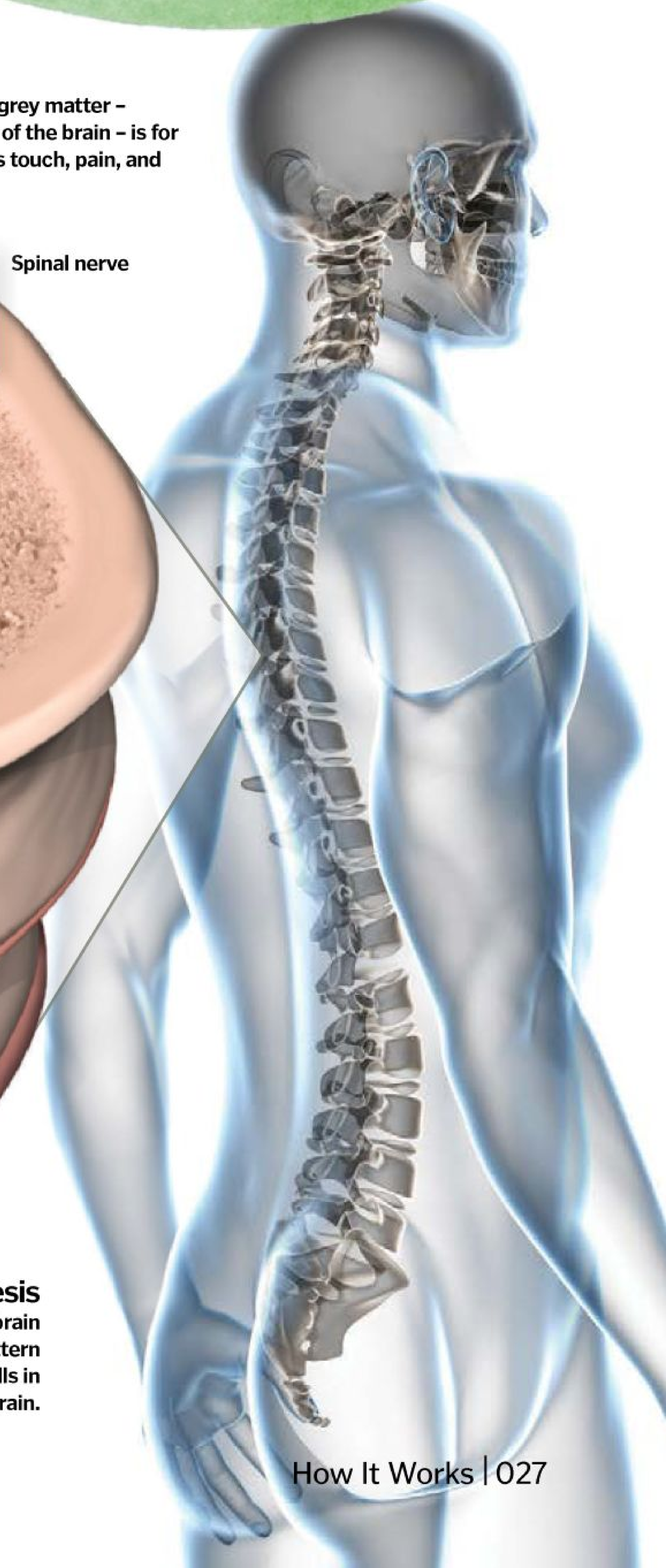
What does the spinal chord do?

The spinal cord actually is part of the brain and plays a major role

Scientists have known for the past 100 years or so that the spinal cord is actually part of the brain. According to Melillo, while the brain has grey matter on the outside (protected by the skull) and protected white matter on the inside, the spinal cord is the reverse: the grey matter is inside the spinal cord and the white matter is outside.

Spinal cord core
In the core of the spinal cord, grey matter – like the kind in the outer layer of the brain – is for processing nerve cells such as touch, pain, and movement.





Grey matter cells
Grey matter cells in the spinal cord cannot regenerate, which is why people with a serious spinal cord injury cannot recover over time. White matter cells can re-generate.

White matter cells
White matter cells in the spinal cord carry the electro-chemical pulses up to the brain. For example, when you are kicked in the shin, you feel the pain in the shin and your brain then tells you to move your hand to cover that area.

Neuroplasticity
In the spinal cord and in the brain, cells can rejuvenate over time when you exercise and become strengthened. This process is called neuroplasticity.

Neurogenesis
According to Tallal, by repeating brain activities such as memorisation and pattern recognition, you can grow new brain cells in the spinal cord and brain.